earth science

PATHWAYS IN SCIENCE

3

man and energy in space

S I METRIC EDITION

JOSEPH M. OXENHORN

CURRICULUM

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man and
energy in space

PATHWAYS IN SCIENCE

BIOLOGY 1—The Materials of Life
BIOLOGY 2—Built for Living
BIOLOGY 3—The Next Generation

EARTH SCIENCE 1—The Earth We Live On
EARTH SCIENCE 2—Oceans of Air and Water
EARTH SCIENCE 3—Man and Energy in Space

CHEMISTRY 1—The Materials of Nature
CHEMISTRY 2—Chemistry of Mixtures
CHEMISTRY 3—Chemistry of Metals

PHYSICS 1—The Forces of Nature
PHYSICS 2—Matter and Energy
PHYSICS 3—Sound and Light

GLOBE BOOK COMPANY

earth science

3

man and energy in space

S I METRIC EDITION

JOSEPH M. OXENHORN

Edited by
PETER GREENLEAF

Globe/Modern Curriculum Press

Metric Commission Canada has granted use of the National Symbol for Metric Conversion.

JOSEPH M. OXENHORN, now retired, has served as Head of Department of Biology and General Science, as Assistant Principal, as Elementary School Principal and Junior High School Principal in various New York City schools. Most recently, he was Principal of Theodore Roosevelt High School, Bronx, N. Y. He has headed science syllabus committees and has developed science films. Mr. Oxenhorn is author of Globe's *Pathways in Science* series, *Pathways in Biology* for high schools, and a college textbook of teaching methods for science teachers.

PETER GREENLEAF has served as Chairman of the Science Departments at Montauk Junior High School and Eron Prep School and as an Instructor at the Cooper Union College of Engineering in New York. He was the Supervisor of Audio-Visual Instruction at the New York City Board of Education. He is the author of many science books and numerous related articles, films and filmstrips. He is now Adjunct Associate Professor in Science at Brooklyn College School of General Studies in New York City.

Ruth G. Oxenhorn served as editorial and research assistant in the original and revised editions.

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Introduction to the Students

Welcome to your new science book, *Pathways in Science!*

A pathway is a road, a street or an avenue which leads you somewhere. *Pathways in Science* is a book that will lead you to a greater understanding of science.

This section of *Pathways* is called *Man and Energy in Space*. In this section, you will be studying a branch of science called "earth science." Earth science is the study of the earth: what it looks like, what it is made of, what forces act on it and how it relates to other bodies in space. It is an exciting science and will answer many questions for you.

Pathways is a tool to help you learn. A good mechanic knows his tools. A good student knows how to use his book.

Let us study the organization of the book and see how to use it.

ARRANGEMENT

At the front of the book is a *Table of Contents*. This table or list tells you what you can find in the book. It tells you on what page each part of the book can be found.

The book can be divided into four parts called *Units*.

Unit I	Review and Preview	page 1
Unit II	In Our Universe	page 19
Unit III	Energy and Motion in Our Solar System	page 71
Unit IV	Off Into Space	page 141

Each unit is divided into *Chapters*. Each chapter begins with a *Target Question* which is answered by material in that chapter. For example, on page 3, you will find Chapter 1. The Target Question is "What do I remember about the science of the atmosphere and space?"

Each chapter is divided into *Paragraphs* which have a number. Turn to page 3. There you will find Paragraph 1, *Looking Back . . .* Paragraph 2 on the same page is titled *Our Earth in Space*.

Every few paragraphs, you will find a section called *You Now Know*. Turn to page 13 for an example. This is a kind of summary of what you have just read. It helps you review. It helps you remember.

At the end of each chapter, you will find questions which help you find out how much you have learned. Turn to page 7. There you will find the section called *Understanding What You Have Read*. In addition to the questions, you will also find suggestions for exciting things you can do at home. Look at page 14 in Unit I, Chapter 2. Question VI is *For the Amateur Scientist.*

NEW SCIENCE WORDS

Science has its own language. It has new words which have a special meaning. Some of these new words are unfamiliar. The book tells you how to pronounce these words. Turn to page 3. In Paragraph 2, we use the word ASTRONOMY. Notice how it is pronounced: (uh-STRON-o-mee).

At the end of each Unit, there is a *Glossary*. Turn to page 15. Notice that the words are arranged in alphabetical order. In Column 2, the words are pronounced. In Column 3, there are simple definitions.

PICTURES AND DIAGRAMS

The book has many pictures and diagrams, called figures, to help you "see" science ideas. All pictures and diagrams are numbered in such a way that you can find them quickly. For example, Fig. 10–1 means the first picture on page 10. Fig. 10–2 means the second picture on page 10.

INVESTIGATIONS

Pathways has many investigations (experiments). Some of them you will see your teacher do in class. Some you will do in class by yourself or with a partner. Some you can do at home. Experiments are jobs that give a scientist answers. They are great fun and a good way to learn. A list of the investigations in this book can be found on page viii.

SOME HINTS FOR A GOOD STUDENT

1. Listen carefully to your teacher.
2. Watch the experiments.
3. Get a good notebook. Keep it clean and neat.
4. Do your homework every day.
5. Read the book carefully. If you don't understand something the first time, read it again.
6. If you need more help, ask your teacher.
7. Don't mark up your book. Keep it clean.

AND REMEMBER . . .

School can be fun. School means learning. If you study today, you will succeed tomorrow. Good luck!

THE AUTHOR

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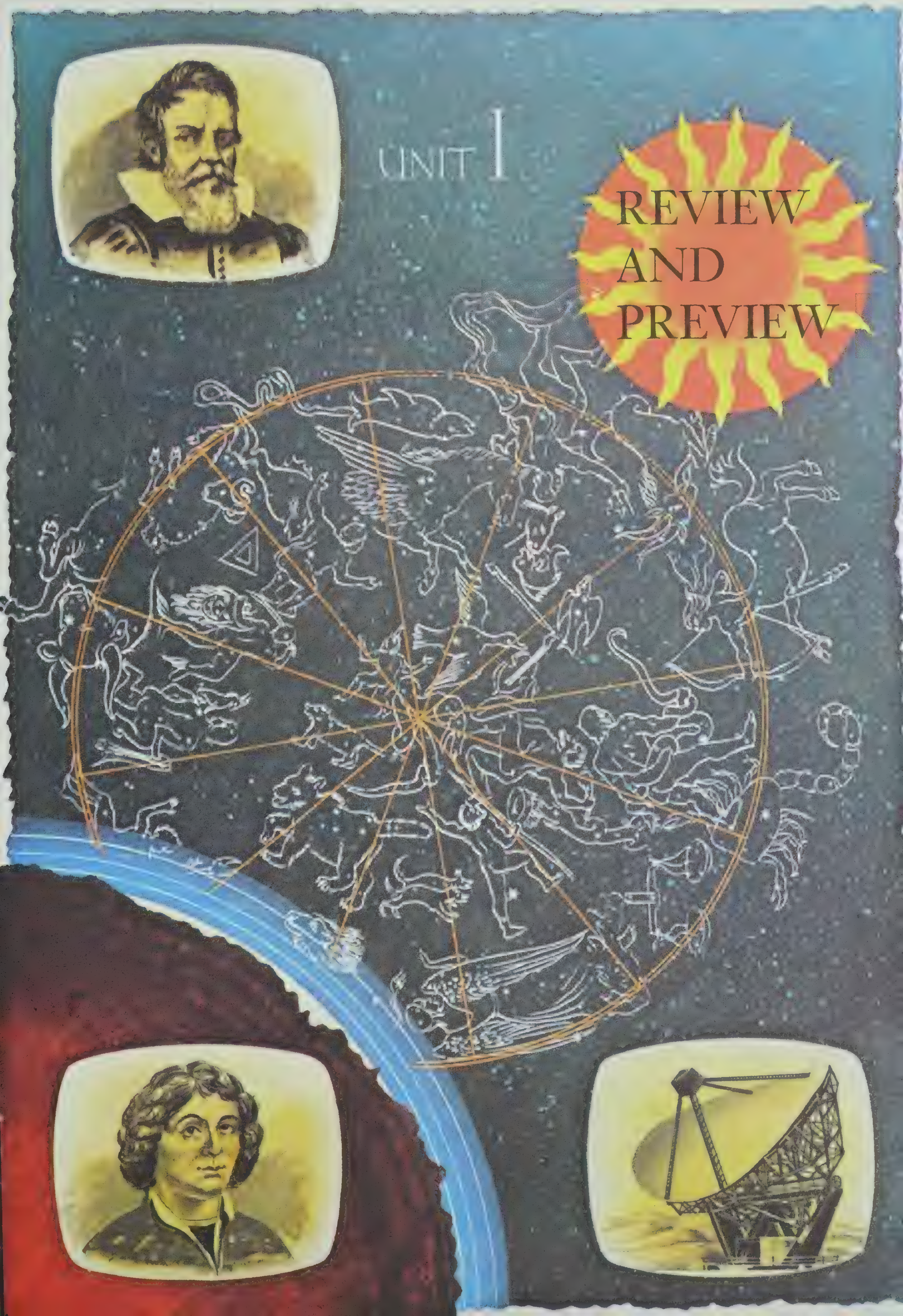
Galileo, an Italian astronomer (top left) was the first to use a telescope to view the heavens. Nicolaus Copernicus (bottom left) developed the idea of the universe with the sun at the center. The constellations (center) are shown by the animals they represent. The earth and its atmosphere are shown in the bottom left corner. A radio telescope (bottom right) uses radio waves to "see" into the universe. The earth revolves around the sun (top right).

UNIT 1

REVIEW AND PREVIEW



UNIT I

Review and Preview

CHAPTER 1. IMPORTANT IDEAS

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1

TARGET
What do I remember about the science of the atmosphere and space?

Important Ideas

1. LOOKING BACK . . .

In your earlier studies, you saw that the major ideas in science keep coming up again and again. Even though you seem to be studying only one branch of science, you keep hearing many of the same theories and the same laws. This is true because many of the same forces of nature work together.

Look at Fig. 3–1. The chart shows the four big branches of science. Each branch in the red circle is divided to show some smaller special branches. Of course, the chart is not complete. Can you give a few "key words" to show what areas of knowledge are included in the four main divisions?

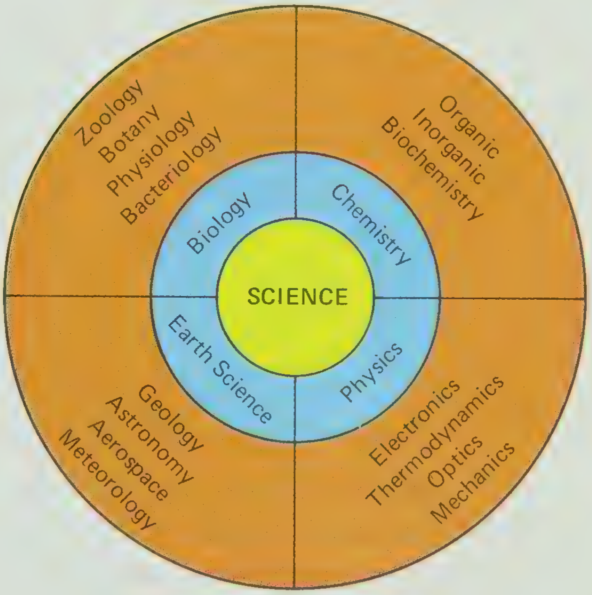


Fig. 3–1

This chart is not complete. Can you suggest some branches which have been left out?

2. OUR EARTH IN SPACE

The name of your new science book is *Man and Energy in Space*. Look again at Fig. 3–1. The two branches of science we shall look at are ASTRONOMY (uh-STRON-o-mee) and AEROSPACE (AIR-o-space) science. Whether you study either astronomy or aerospace science, you will come back to the larger forces of nature and the proven laws of science in *all* fields.

3. WHAT ARE THE FORCES OF NATURE?

You have learned that most changes

around us result from changes in matter and changes in energy. The major forces in our universe are GRAVITATION (GRAV-i-TAY-shun) and ELECTROMAGNETISM (ee-LEK-tro-MAG-na-tizm). From these forces, you get light, heat and chemical energy. These enable you to do work.

4. OUR PLACE IN NATURE

You live on one small planet, the *earth*. The earth's surface, which is made up of the LITHOSPHERE (LITH-o-sfeer) and the HYDROSPHERE (HY-dro-sfeer), is affected by the forces of nature. You, too, are controlled by the forces of nature. The earth is surrounded by a gaseous envelope, the ATMOSPHERE (AT-mus-feer), which is made of many layers. The forces of nature affect the layers of the atmosphere and cause physical and chemical changes on the earth.

Our planet is part of our *solar system.* A star called the *sun* is at its center. The rest of the universe is made up of other stars, some of which are believed to have planets revolving around them. These are also solar systems. Once again, we use the same laws of chemistry and physics to explain the actions of the stars and planets.

5. ENERGY IN THE UNIVERSE

Energy is the ability *to do work* or *to change matter*. Matter, as you know, is everything around us. Look around your classroom. Everything in it is made of matter.

Natural energy in our universe depends on *radiant sun energy*. Radiant sun energy is light energy. It can cause physical and chemical changes. Light energy can be changed to other forms of energy.

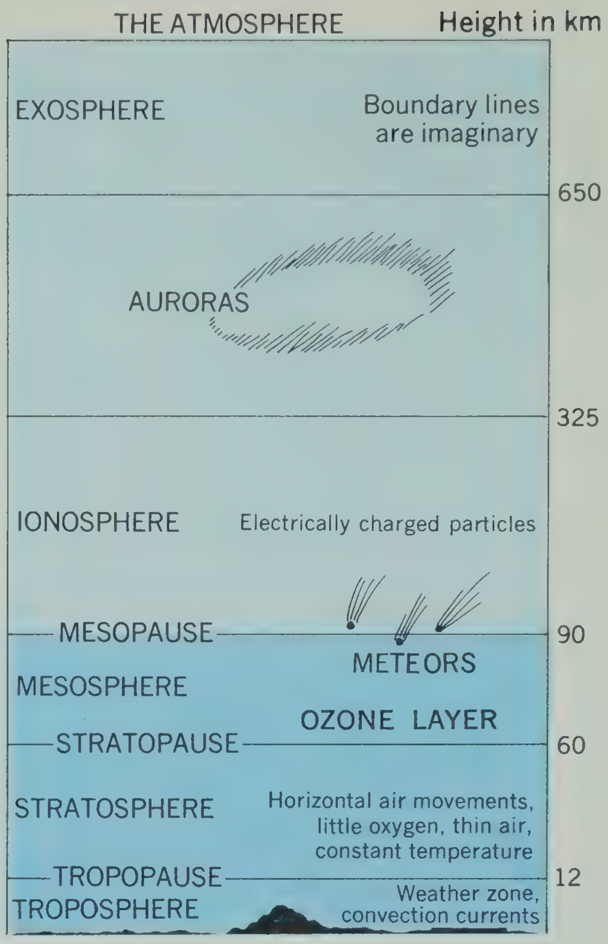

THE ATMOSPHERE
Height in km
EXOSPHERE
Boundary lines are imaginary
650
AURORAS
325
IONOSPHERE
Electrically charged particles
MESOPAUSE
90
METEORS
MESOSPHERE
OZONE LAYER
STRATOPAUSE
60
STRATOSPHERE
Horizontal air movements, little oxygen, thin air, constant temperature
TROPOPAUSE
12
TROPOSPHERE
Weather zone, convection currents

Fig. 4–1

6. THE SUN IS A BALL OF VERY HOT GASES

The sun is a ball of very hot gases. It is more than 100 times bigger than our earth (in diameter). The sun gives off radiant energy. Radiant energy behaves in two ways: (1) either in the form of lightwaves; or (2) as bundles of energy called PHOTONS (FOH-tons). The waves differ in rate of vibration. They also differ in *wavelength*. The photons travel from the sun to the earth at a speed of about

LIGHT ENERGY CAN BE			
TAKEN IN:	SENT THROUGH:	BOUNCED BACK:	BENT:
ABSORBED	TRANSMITTED	REFLECTED	REFRACTED

Radiant Sun Energy

- Invisible Heat Waves
- Visible Light Waves
- Invisible Ultraviolet Rays
- X rays, Gamma Rays

300 000 km/s. They travel the distance of 150 million kilometres from the sun to the earth in 8.3 min.

As this energy travels through space, it causes many changes in our atmosphere and on our earth. Some of this energy reaches the earth as light rays. The light is transmitted, absorbed, reflected or refracted, depending on the objects or materials that it reaches.

7. LIGHT AND SHADOWS

As light travels through space, some

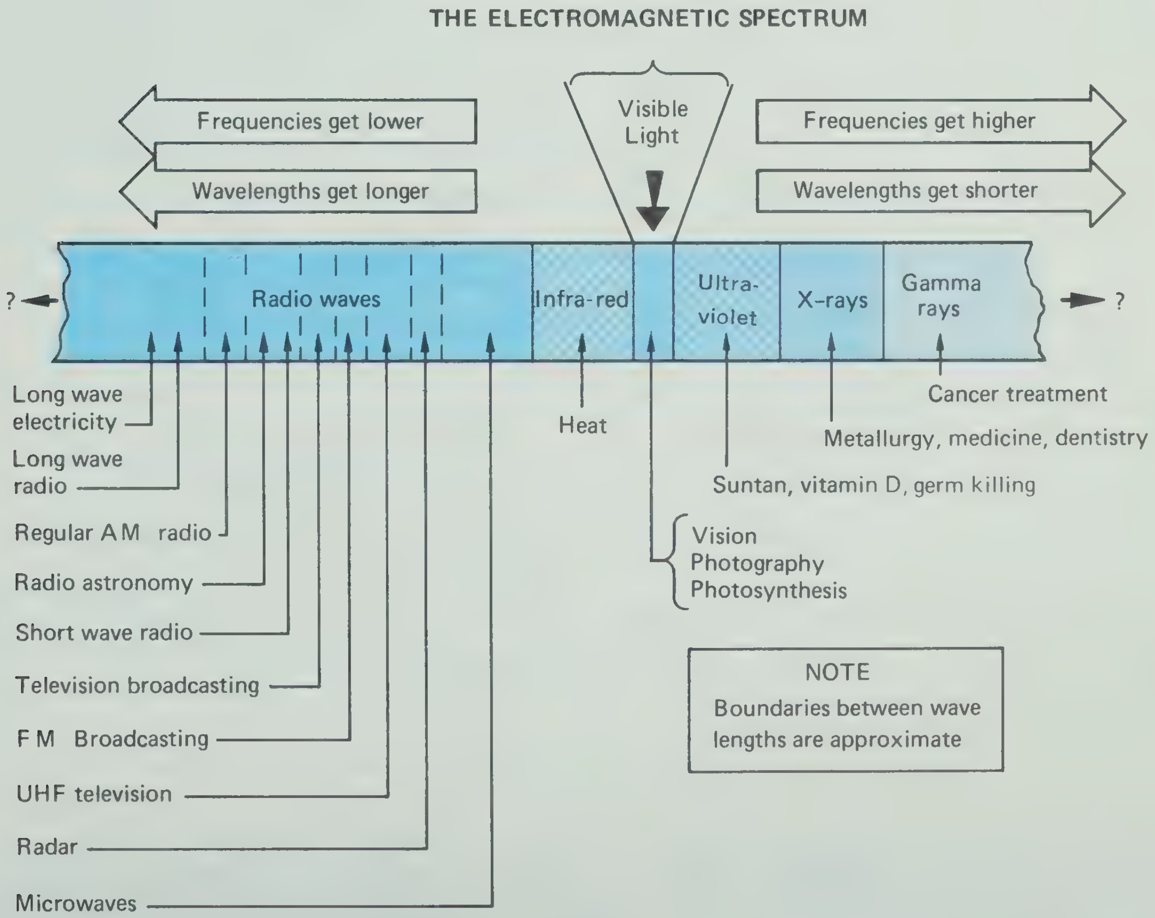


Fig. 5–1

The electromagnetic spectrum is formed by radiation (radiant energy) from the sun.

planets or satellites may block its path. An OPAQUE (o-PAYK) object blocks the path of light. A dark area is one which is formed behind the object. The *shadows* formed this way take their shape from the object which blocks the light. The size of the shadow depends on the distance between the object and the light, and on the size of the object.

8. GRAVITY—THE FORCE OF ATTRACTION

The force of gravity is not fully understood by scientists. However, they do know that the earth exerts a pull which keeps objects on its surface. This same kind of force is called gravity. Gravity pulls objects toward the center of the earth.

Sir Isaac Newton (EYE-zik NEW-ton) opened the door to thousands of secrets in our universe when he stated his *Law of Gravitation*. This law states, "Every particle of matter in the universe attracts every other particle." The Law of Gravitation can help us to better understand *energy*, *motion* and *inertia*. The earth attracts the moon and keeps the moon in its path (orbit). All planets in our solar system attract each other by gravitation.

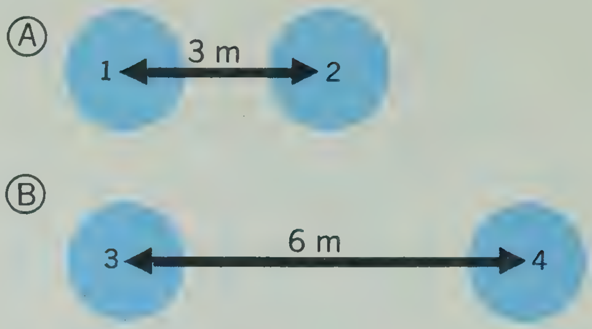


Fig. 6–1

In Diagram A, the two objects will have four times as much attraction for each other as in Diagram B. How is this possible?

9. HOW MUCH ENERGY? HOW MUCH MATTER?

When you studied energy, you saw that it can be changed from one form to another. When you studied chemical changes, you saw that matter can be changed from one form to another. Sometimes different kinds of matter can combine to form matter with new properties. These observations led us to a scientific law.

LAW OF CONSERVATION OF MATTER AND ENERGY

Matter can be changed into energy in some reactions. But, the total amount of energy and the total amount of matter in our universe remains the same.

Strength of Gravitational Pull

1. Distance between centers of objects
2. Amount of mass in the objects

UNDERSTANDING WHAT YOU HAVE READ

I. What are the two main ideas in Chapter 1?

1. This book deals with energy in space.
2. Gravity is an ever-present force.
3. Matter and energy are explained by the laws of nature.
4. Light and shadows are related.

II. In which paragraph do you find the answer?

1. What was Newton's contribution to our knowledge of space?
2. Can matter be changed to energy?
3. How are photons and wavelengths related to energy?
4. To what group of space bodies does our earth belong?

III. Knowing What and Why

1. Radiant sun energy can be changed to
   - a. protons.
   - b. protons and electrons.
   - c. heat waves.
   - d. gravitational energy.
2. Shadows are formed when light waves are
   - a. stopped by opaque objects.
   - b. changed to a visible spectrum.
   - c. refracted by lenses.
   - d. reflected by polished surfaces.
3. The Law of Conservation of Matter and Energy is shown
   - a. when a shadow is formed on the sun.
   - b. each time a magnet attracts iron.
   - c. when dynamite explodes a hill.
   - d. when objects fall to the ground.
4. The major forces in our universe are
   - a. oxidation and combustion.
   - b. photosynthesis and kinetic energy.
   - c. gravitation and combustion.
   - d. gravitation and electromagnetism.

IV. Finish the story by filling in the blank spaces. Choose the correct words from the list below.

Our earth is a (1). The earth is surrounded by the (2). Its surface is made up of the (3) and the (4), and is controlled by the (5). The forces of nature give us light, (6) and (7) energy. The center of our solar system is the (8).

heat
sun
chemical
gravity
lithosphere
forces of nature
atmosphere
planet
hydrosphere
combustion

V. Unscramble the Letters

Read the first letters down. You get an instrument for studying the sky. Answer is on Page 54.

1. UEMTPERTARE (hot or cold)
2. EENRYG (ability to do work)
3. ITLHPEOSHRE (part of earth's surface)
4. CLETONER (atomic particle)
5. RATS (the sun, for example)
6. ROCE (center of the earth)
7. AXOIDTONI (combining with oxygen)
8. LTAPNE (the earth)
9. GEINEN (drives a machine)

1. _ _ _ _ _ _ _ _ _ _ _
2. __ __ __ __ __ __
3. _ _ _ _ _ _ _ _ _ _ _
4. __ __ __ __ __ __ __ __
5. __ __ __ __
6. __ __ __ __
7. __ __ __ __ __ __ __ __ __
8. __ __ __ __ __ __
9. __ __ __ __ __ __

2

TARGET
What shall I learn in earth science this year?

Astronomy and Aerospace: Twin Sciences

Fig. 8–1
The sun was a mystery in ancient times. It still is.

1. THE ROMANCE OF THE HEAVENS

The sky has always meant wonder and mystery. What was that ball of hot gases called the sun? Why was it sometimes a fiery red? Why did it seem to move? And when night came, why did the stars shine in the darkness?

Sailors guided their ships across strange waters by gazing at the stars. Wise men used the stars to tell the fortunes of kings. Poets wrote love songs about the moon. Men trembled at the sight of an eclipse. Everywhere men told time by the heavens. The seasons followed the path of the sun. The heavens were full of romance. But there were some for whom this study was a science.

2. ASTRONOMY: GRANDPARENT OF THE SCIENCES

It should not surprise you to hear that *astronomy* was probably the first of the sciences. Astronomy is the science of the heavens, the stars, the planets and the satellites which are in space.

You must not confuse astronomy, which is a science, with ASTROLOGY (uh-STROL-o-jee), which is a PSEUDOSCIENCE (SOO-do-SY-ens). A pseudoscience is a false science; it pretends to be correct. Thousands of years ago, when people were uneducated and superstitious, they thought the stars could control a person's future. This idea is still believed by some people who draw up HOROSCOPES (HOR-uh-skopes). These are still good for a laugh, as long as you don't take them seriously.

TODAY'S HOROSCOPE
LEO JULY 23—AUGUST 22

The stars are in your favor today. Now is the time to discuss important matters with family or friends. Also, look for an old friend to reappear.

3. THE BEGINNINGS OF ASTRONOMY

Astronomy, as a science, began in ancient times. Observations were made by eye. Careful notes were taken and compared. Mathematics was used to figure the distance and speed of the stars and planets.

Much of ancient astronomy was learned in Alexandria, in Egypt. There, in 250 B.C., ERATOSTHENES (er-uh-TOS-thuh-neez) figured out the circumference of the earth. About

Fig. 9–1

Fig. 10–1

A horoscope may be fun. However, it certainly is not science.

150 A.D., Ptolemy (TOL-uh-mee) drew up a plan of the heavens. In this plan, the earth was put at the center. All other bodies, such as the sun and planets, moved around the earth. Later, astronomy was studied in ancient Arab countries. Instruments and mathematics were used to study the stars.

You will learn the great names of astronomy in later chapters. You will hear of the Polish astronomer, Nicolaus Copernicus (NIK-uh-lus ko-PUR-ni-kus); the Danish scientist, Tycho Brahe (TEE-ko BRAH); and the German scientist, Johannes Kepler (yo-HON-is KEP-ler).

About 1610, the Italian scientist *Galileo* opened a new chapter in astronomy. He was the first to use a *telescope* to look at the sky. Now, a new look at the heavens could show us what our eyes alone could not see. The "slow walk" of astronomy speeded up to a run.

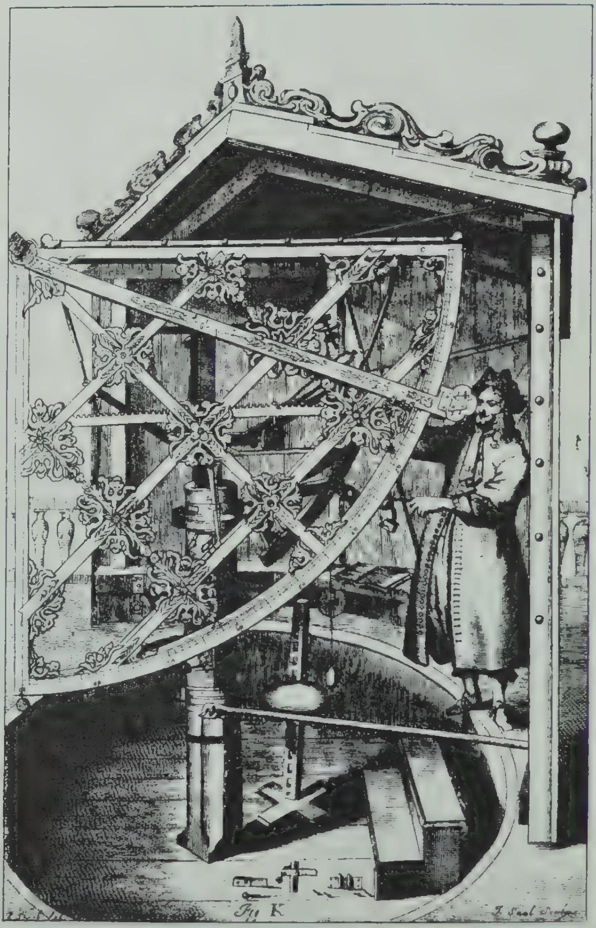


Fig. 10–2

Ancient instruments were used to figure the position and the distance of stars.

YOU NOW KNOW

- Astronomy is the science of our universe and the bodies in it; sun, stars, planets and so forth.
- Ancient astronomy depended on naked-eye observations and instruments for figuring angles and distances.
- A new age in astronomy came in 1610 when Galileo used the telescope to study the heavens.
- The Space Age opened with the launching of Sputnik I in 1957.

4. HOW DOES THE ASTRONOMER SEARCH FOR ANSWERS?

Astronomy is a science; astronomers use a scientific method. Notice, we said *a* scientific method; not *the* scientific method. That's because there are many ways to get scientific answers. However, there is a general set of procedures which scientists usually follow. Their search for answers begins with a *problem.*

Then astronomers use *observation* with their senses. They help the senses by using special instruments. In this way they collect facts and figures. While they're busy collecting observations, they keep asking questions. They may propose a temporary answer, a HYPOTHESIS (hy-POTH-uh-sis). They may develop a stronger explanation, the THEORY (THEE-uh-ree).

While this is going on, scientists are performing EXPERIMENTS to test ideas. Finally, they may develop scientific LAWS OR GENERALIZATIONS (JEN-uh-rul-uh-ZAY-shuns). If these generalizations work, they may be able to *apply* this knowledge. For example, they may develop space vehicles and send weather satellites into space.

When is a scientist's work done? Really, never! Scientists always search for new answers and new explanations.

5. MEASUREMENTS IN ASTRONOMY

Precise measurements are very important in the science of astronomy. Most of the questions that we have in astronomy concern measurement. Some examples are: How far away is the North Star? How long will it take for Venus to go once around the sun? How hot is the surface of Jupiter? At what angle from the earth does the sun look the reddest? If you think clearly, you will see that the most important measurements are distance, angle, time and temperature.

6. UNITS OF MEASUREMENT

Measurement is the act of taking measure. It is really a comparison. We compare the size, mass or volume to a known amount. We compare temperature (the degree of heat) to a known degree. The known amount is called the *standard unit*.

In astronomy and aerospace science, distance is a very important unit. Astronomers are also interested in mass (and weight), in volume, and in temperatures. Astronomy is a *precise* science. It is not enough to say "about 3000 km." It is more useful to say "3253.14 km."

7. SYSTEMS OF MEASUREMENT

Common measurement throughout the world is in the metric system. In North America we used the English system of measurement until very recently. In a few years we will have "gone metric" completely. The metric system is a decimal (tens) system. All units are related to each other by the figure 10.

milli = 0.001 of a unit: mm = 0.001 m
centi = 0.01 of a unit: cm = 0.01 m
kilo = 1000 x a unit: kg = 1000 g

In the measurement of *temperature* (the degree of heat), the English scale is FAHRENHEIT (FAR-un-hyt). The metric system uses the CELSIUS (SEL-see-us) scale.

In both systems, time is measured in seconds, minutes, hours, months and years.

The metric system will make our everyday measuring easier. Can you think of some reasons why?

8. A NEW UNIT FOR DISTANCE

When we think of distance, we think of millimetres, metres and kilometres. Would you measure the earth's circumference in millimetres? Of course not! You can quickly see that only one of these, kilometres, is useful. We still say that the sun is 150 000 000 km from us. But when you start thinking of stars, which are much farther away, kilometres mean nothing. When you studied light you saw that it travels at a speed of 300 000 km/s. In one year, light travels over 9.5 trillion kilometres. This is the origin of the term *light-year*. But we now measure distance in space in PETAMETRES (PET-uh-mee-ters). One light-year is the equivalent of 9.46 Pm (petametres).

Our nearest star is Proxima Centauri (PROX-i-ma sen-TAW-ree). The light you see from that star left the star 4.27 years ago. So Proxima Centauri is four and a quarter light-years away, or 40.4 Pm.

9. ANGLES ARE IMPORTANT

The angles made by stars and other stars, by stars and planets, and by planets and the earth are very important. Angles affect light and shadows.

Fig. 12—1

These boys are looking at an instrument called a sextant. It is used for measuring the angles that stars make with the earth's horizon.

Angles can be used to measure distances by math formulas. Do you remember angles from your math? Let us review.

1. An angle is formed when any two lines meet. Fig. 13–1 shows many angles.
2. Some angles are narrow; some are wide.
3. All angles are measured in degrees (°). (See middle figure below.)
4. A full circle is 360°. A half circle is 180°.
5. Angles can be from anything over zero to 360°.

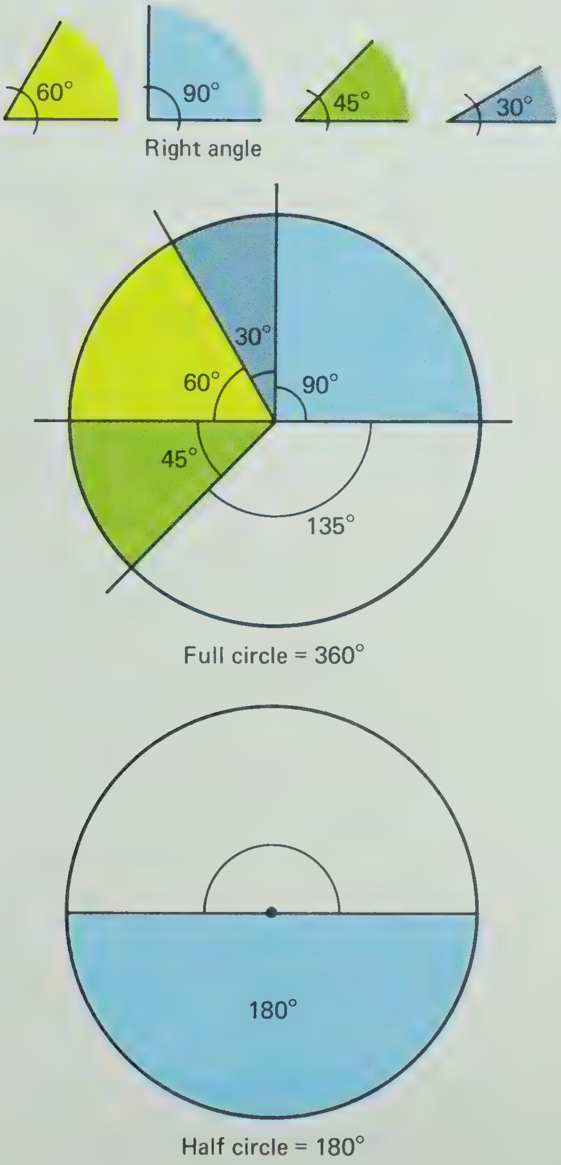


Fig. 13–1

YOU NOW KNOW

- Astronomy must be studied through careful measurements.
- Some important measurements used are distance (in kilometres and petametres), angles (in degrees), temperature (in degrees Celsius) and time (in standard time units).

10. WHAT'S AHEAD?

What is a star? How far away is it? Why do we not see all the stars? Why is there a difference in the appearance of the moon from night to night? Why do the Chinese and Hebrew calendars have thirteen months? What are tides and how do they rise and fall?

At one time, an expression to show all lack of hope was, "It's like reaching for the moon." Today, you know that reaching for the moon is not hopeless. We have already landed men on the moon. The question is, how do we get people into space? How long is it safe to let them travel in space? What are the problems of space travel? These, and other similar questions, will be answered in this book. The earth sciences make up an exciting branch of science which you will enjoy. *Off we go!*

UNDERSTANDING WHAT YOU HAVE READ

I. What are the two main ideas in Chapter 2?

1. Astronomy studies the skies and the objects in space.
2. Sputnik I is important in space study.
3. Astronomy began in ancient days and has grown since then.
4. Proxima Centauri is a star.

II. Explanation, Please . . . answer in one or two sentences.

1. What is astrology?
2. Who was Eratosthenes?
3. What single invention gave astronomy a new "push"?
4. What is a petametre?

III. Knowing What and Why

1. Astronomy needs measurements of all *except*
    - a. angles.
    - b. odors.
    - c. shadows.
    - d. masses.
2. In ancient days of astronomy,
    - a. Tycho Brahe invented a microscope.
    - b. Ptolemy drew up a scheme of the universe.
    - c. Copernicus developed the first telescope.
    - d. Newton explained ionization.
3. Sputnik I is
    - a. an unknown element in the spectrum.
    - b. a man-made satellite.
    - c. Russia's answer to radar.
    - d. a Russian space scientist.
4. Early navigators guided their ocean voyages by
    - a. using spectroscopes.
    - b. watching ocean currents.
    - c. noting the position of the stars.
    - d. using sonar devices.

IV. True or false? Explain your answer.

1. Astrology can predict the next eclipse of the sun.
2. Since we cannot reach the sun, we have no way to know its temperature.
3. A light-year is a measure of long periods of time.
4. Astronomy can be studied only at night.

V. Number, Please

1. Which has more degrees, a quarter of a circle or half of a circle?
2. How fast is the speed of light?
3. How far is the sun from the earth?
4. If the distance to the moon from earth is 386 400 km, how far is it from the moon to the sun when the moon is between the earth and the sun?
5. Which is the longest in any circle: radius, circumference or diameter?

VI. For the Amateur Scientist

Begin looking at the skies at night.

1. Keep drawings of the shape of the moon for a full month. You will study the moon later.
2. Keep records of the time of sunrise and sunset each day. Check with the newspaper. Many newspapers publish this daily.

VII. Put on Your Thinking Cap

Look at the horoscope in Paragraph 2. Why is this unscientific? Can you see that it might even be harmful? Explain.

Glossary: What Does It Mean?

aerospace science	AIR-o-space	The science that studies all space past the earth's surface. It includes the atmosphere and outer space.
astrology	uh-STROL-o-jee	The study of the stars in relation to their influence on man's affairs. It is a false or pseudoscience.
astronomy	uh-STRON-o-mee	The science that studies the heavenly bodies. One of the oldest of sciences.
atmosphere	AT-mus-feer	The gases which surround the earth's surface and other heavenly bodies.
Brahe, Tycho	BRAH, TEE-ko	The Danish astronomer (1546–1601) who first studied the Nova and made precise studies of planet positions.
Celsius	SEL-see-us	A thermometer whose scale is in metric units.
Copernicus, Nicolaus	ko-PUR-ni-kus, NIK-uh-lus	The Polish astronomer (1473–1543) who set forth the principles of a sun-centered solar system.
electromagnetism	ee-LEK-tro-MAG-na-tizm	The term used to describe all radiation from the sun such as gamma rays and radio waves.
Eratosthenes	er-uh-TOS-thuh-neez	The Greek astronomer (275–192 B.C.) who first determined the circumference of the earth.
Fahrenheit	FAR-un-hyt	A thermometer whose scale is in English units.
Galileo		The Italian astronomer (1564–1642) who first used the telescope to study the heavens.
generalization	JEN-uh-rul-uh-ZAY-shun	See *law.*

gravitation	GRAV-i-TAY-shun	The attraction of all matter in the universe by all other matter.
gravity		The force that pulls all bodies on or near the earth towards its center.
horoscopes	HOR-uh-skopes	Drawings used in astrology which show the positions of the sun, moon and planets. They are used to tell a person's future.
hydrosphere	HY-dro-sfeer	The part of the earth's surface that is covered with water.
hypothesis	hy-POTH-uh-sis	A temporary explanation for a natural event; often a "hunch" or an "educated guess."
inertia		The property of a body to remain at rest or in motion unless acted on by an outside force.
Kepler, Johannes	KEP-ler, yo-HON-is	The German astronomer (1571–1630) who set up three laws of planetary motion.
law, scientific		An explanation backed up by many experiments; an explanation that seems to work most of the time; a generalization.
lithosphere	LITH-o-sfeer	The part of the earth's surface that is solid, such as the continents.
metric	MET-rik	The system of measurement based on the metre in which all units are in decimals (10's).
Newton, Sir Isaac	NEW-ton, EYE-zik	The English physicist and astronomer (1642 – 1727) who developed the three laws of motion and the Law of Gravitation.
opaque	o-PAYK	The property of an object that will not allow light to pass through it.
petametre	PET-uh-mee-ter	The unit used to measure distance in space.
photon	FOH-ton	A unit or package of radiant energy.

Proxima Centauri	PROX-i-ma sen-TAW-ree	The star (other than the sun) nearest the earth.
pseudoscience	SOO-do-SY-ens	A false science.
Ptolemy	TOL-uh-mee	The Egyptian astronomer who, in the second century A.D., set up the system of an earth-centered universe.
radiant energy		Energy that is given off by the sun in the form of waves, such as X rays.
satellite	SAT-uh-lyt	Any heavenly body, man-made or natural, that orbits a larger heavenly body. The moon is a satellite of the earth.
shadow		The dark area formed when an opaque object blocks the path of light.
solar system		The 9 planets, satellites, comets, asteroids and meteors that are in orbit around the sun.
space		The area past the earth's atmosphere.
sphere	SFEER	A circular or round body such as a ball.
sun		The medium-sized yellow star that is the center of our solar system.
telescope	TEL-uh-skop	An instrument which uses lenses, mirrors or radio waves to observe a distant object.
theory	THEE-uh-ree	An explanation based on some facts; to be tested again and again by experiments.
universe	YOU-ni-vurs	All matter, energy and space.

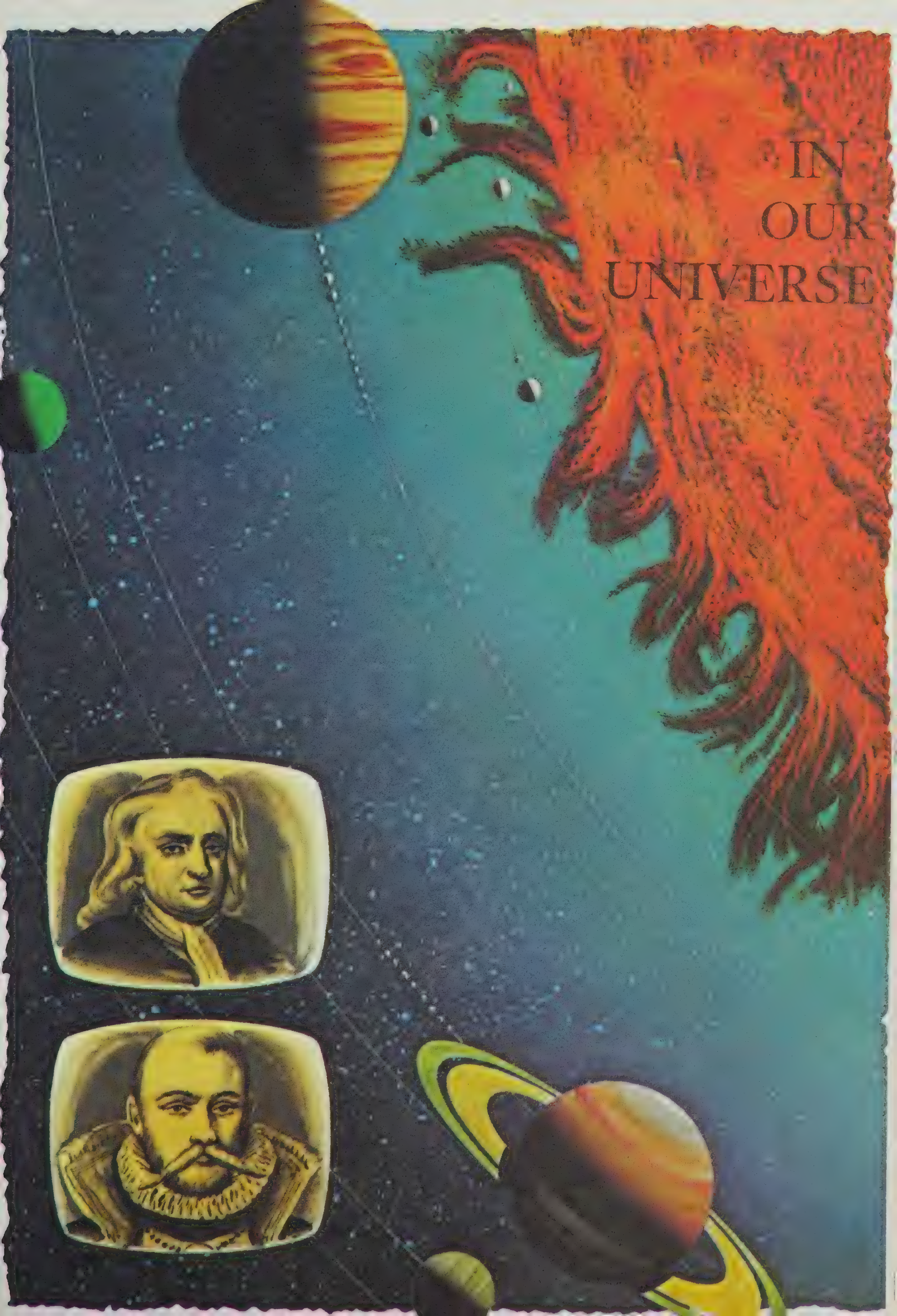
ANSWER TO PUZZLE VI, PAGE 169

1. RockEt, 2. LauNch, 3. ApOllo, 4. BooSter
ANSWER: **ENOS**

UNIT II

The nine planets of our universe are shown in their positions around the sun. Their relative size is also shown. Notice the size of the sun in relation to the planets. The sun is a star. In the top television screen (bottom left) is Sir Isaac Newton, the English physicist who developed the laws of motion. In the bottom screen is Tycho Brahe, the Danish astronomer who made precise studies of the planets.

IN OUR UNIVERSE



UNIT II

In Our Universe

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3

TARGET
How do astronomers study the heavens?

Looking Skyward

1. WHY DO WE STUDY ASTRONOMY?

We are curious animals. We want to know all about nature. Ever since the earliest days, we have looked toward the heavens with wonder. Now, we are beginning to understand more about the heavens and the bodies in it.

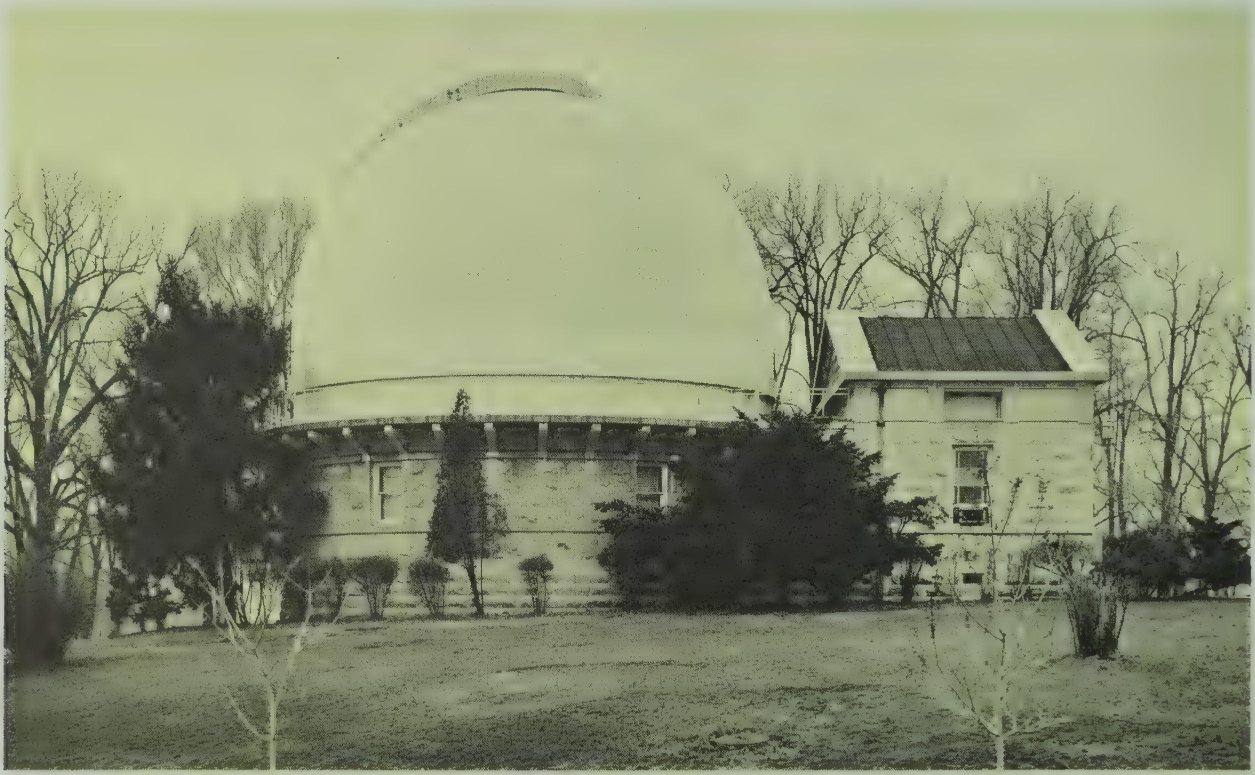


Fig. 22–1
This observatory is useful for the study of astronomy. What is the most important instrument in the observatory?

Studying astronomy has had other results besides satisfying our curiosity. Astronomy is the basis for telling time. It explains the seasons. For centuries, sailors have used the stars as a method of NAVIGATION (nav-i-GAY-shun). More recently, studying the skies has helped us to understand and predict the weather. It has also helped us to develop new forms of communication such as radar, radio and TV.

Now we have entered the Space Age. As we land more astronauts on the moon, we may discover new and useful materials. The study of astronomy and space is a fascinating and useful branch of science.

2. WHO STUDIES ASTRONOMY?

There are many students of astronomy. There are, of course, the ASTRONOMERS (uh-TRON-uh-mers) who study the stars and the planets. When you studied weather, you saw that METEOROLOGISTS (MEE-tee-or-ol-o-jists) study the atmosphere. *Chemists* are interested in the materials found in planets and in stars. *Physicists* study the radiations of stars. Radio and TV *engineers* study space and the atmosphere for planning and designing their receivers and transmitters. *Geologists* are interested in the rocks on planets and stars.

Finally, we must not forget the amateur. Amateur scientists are very often the first people in a new science. Even today, when astronomy is a highly developed science, amateurs make many observations. These observations can help the scientists. Of course, amateur astronomy is a good outdoor hobby. Perhaps you, too, can enjoy this hobby.

Fig. 23–1

Astronomy is an exciting hobby for people of all ages.

3. WHERE IS ASTRONOMY STUDIED?

Astronomy, the science of the skies, usually takes one out-of-doors. The backyard, a city street or an apartment house rooftop may become a "laboratory" for observation.

Astronomers find it useful to study the skies on high mountains where the air is clear and where the views are not blocked. Can astronomy be studied from only one spot? Well, not really. In the ball park, you get different views from different seats. Scientists often go on long trips to other parts of the world to get different views. Many studies have been done on ships on the oceans.

Now, of course, we study astronomy not only on earth, but up in space. Manned and unmanned balloons have gone high into the atmosphere. Manned and unmanned space capsules have gone far into space. In July 1969, we even landed men on the moon.

YOU NOW KNOW

- We study astronomy to find out about our universe.
- Astronomy gives us practical answers about weather, communication, time and the calendar.
- Astronomy is studied on the earth, up in the atmosphere and in outer space.

4. THE ASTRONOMER'S WORKSHOP

When astronomy was first born, scientists spent most of their time simply looking or observing. As the science grew, special buildings were built to house the scientists and their many instruments. Such buildings are called OBSERVATORIES (ob-ZUR-vuh-to-rees).

Ancient observatories were usually buildings that had stone columns. They were placed in such a way as to study the heavens from certain directions. The pillars, as you know, formed shadows to study the positions of the sun. Later, tall towers with balconies and domes were built. In 1561, in Germany, the first observatory with a revolving dome was built.

FAMOUS OBSERVATORIES AND THEIR TELESCOPES

Observatory	*Diameter in cm*	*Location*
Reflecting (Mirror)		
Palomar	510	Mount Palomar, California
Kitt Peak	401	Tucson, Arizona
Lick	304	Mount Hamilton, California
McDonald	272	Fort Davis, Texas
Crimean Observatory	264	Nauchny, U.S.S.R.
Refracting (Lens)		
Yerkes	102	Williams Bay, Wisconsin
Lick	91	Mount Hamilton, California
Paris	83	Meudon, France
Astrophysics	80	Potsdam, Germany
Radio	*Diameter in m*	
Arecibo	305	Puerto Rico
National Radio Astronomy	91	Green Bank, West Virginia
University of Manchester	76	Jodrell Bank, England

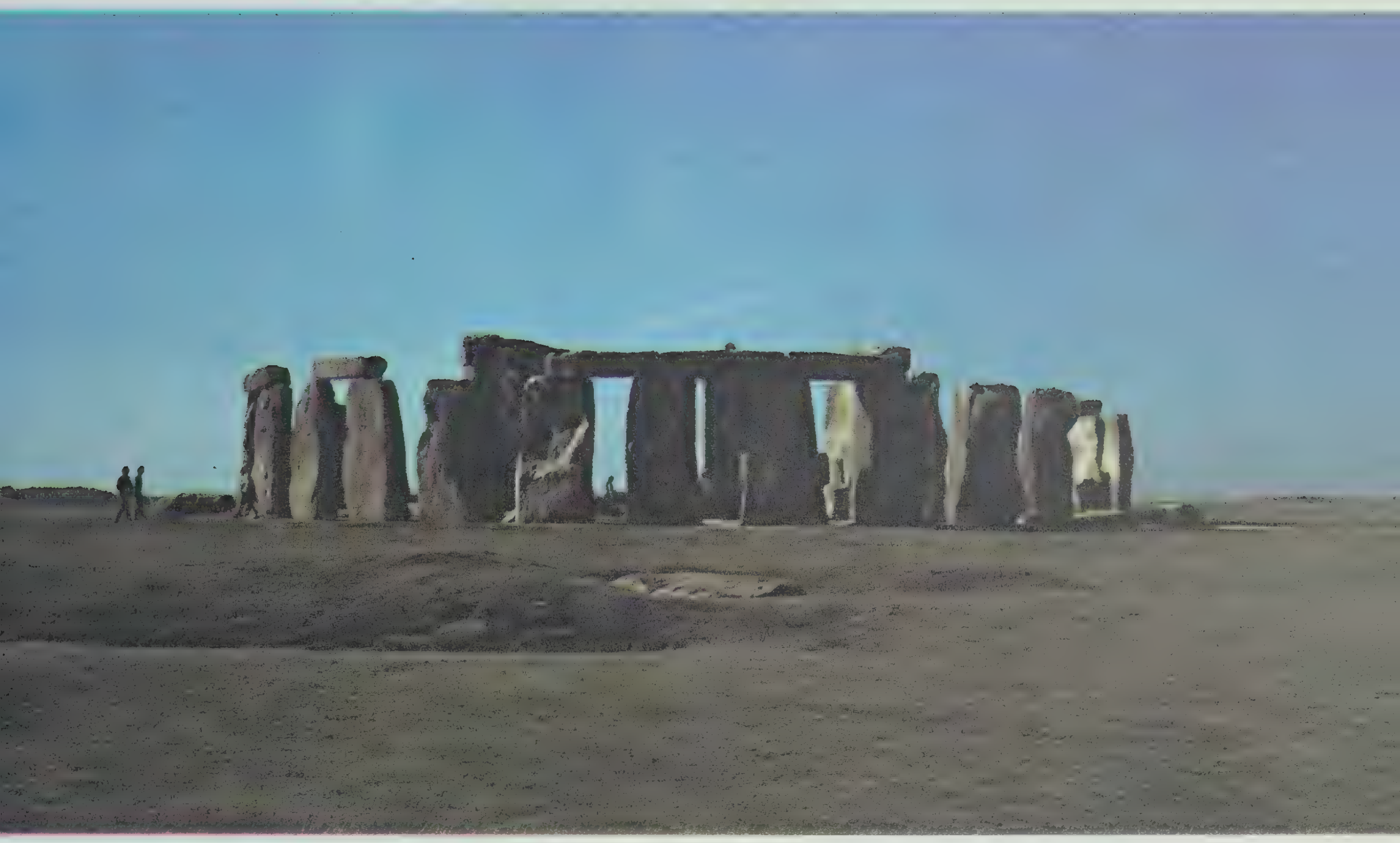


Fig. 25–1

These columns are thought to be part of an ancient observatory. Read about Stonehenge in the encyclopedia.

All modern observatories have at least one powerful telescope. They also contain offices, photographic darkrooms, machine shops and a library. Observatories often have dome-shaped roofs which can be opened by motors to allow the telescope to "look out" into the sky. The dome is a hemisphere (half-sphere) made of metal. The entire dome turns to bring an open slit in line with the lens of the telescope. In some observatories, the floor below the telescope is like an elevator, which can raise or lower the observers.

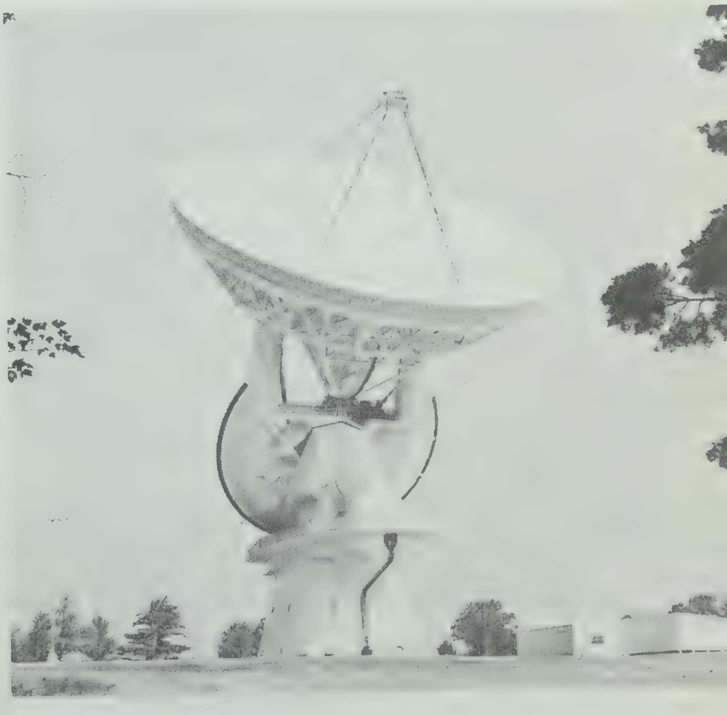


Fig. 25–2

The radio telescope is a new tool for studying the heavens.

5. LET'S VISIT A PLANETARIUM

Perhaps you have already visited a

PLANETARIUM (plan-uh-TAIR-ee-um) building. This is really a special theater which has several special projectors. The projectors show images of stars and planets on a hemisphere dome. Projectors can show movements of stars and planets. The projector can, in a short time, duplicate all the seasons of the year. Some planetariums can duplicate in one hour what you might see in the sky through 25 000 years! Perhaps you are lucky enough to live in a city where there is a planetarium. Your first visit will surely be exciting; you may want to go back again and again.

Famous Planetariums

1. *Charles Hayden Planetarium*
   Boston, Massachusetts
2. *Adler Planetarium*
   Chicago, Illinois
3. *Hayden Planetarium* (American Museum of Natural History)
   New York, New York
4. *Fels Planetarium*
   Philadelphia, Pennsylvania
5. *Buhl Planetarium*
   Pittsburgh, Pennsylvania
6. *McDonnell Planetarium*
   St. Louis, Missouri
7. *McLaughlin Planetarium*
   Toronto, Ontario

6. PUTTING IT ALL TOGETHER

The observations in observatories are recorded carefully. Photographs are collected. Data, collected with many instruments, are recorded. Very often, astronomers compare their notes with other astronomers all over the world.

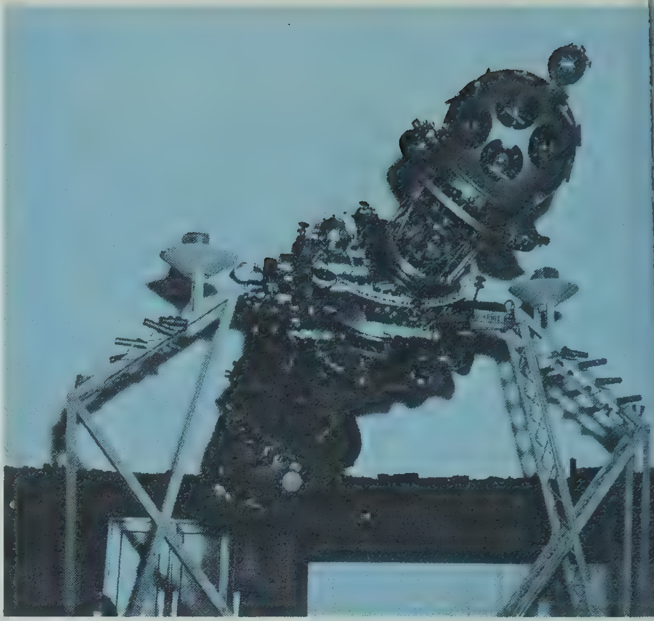


Fig. 26–1

This is the projector in the Adler Planetarium in Chicago, Illinois.

With modern communication it is possible to compare observations at the same time. An astronomer in California, for example, can talk by phone or radio to an astronomer in Australia while an eclipse is taking place. When all the data is put together, scientists can develop new theories and new laws.

YOU NOW KNOW

- Astronomy is studied in observatories which contain telescopes, revolving domes and many instruments.
- A planetarium building has a theater with a projector which shows images of the stars and planets.
- Data from many observatories, when put together, can give us a better understanding of our universe.

UNDERSTANDING WHAT YOU HAVE READ

I. What are the two main ideas in Chapter 3?

1. Astronomy is a form of navigation.
2. Astronomy is studied by observation and experimentation.
3. A trip to the planetarium is very educational.
4. Astronomy is studied outdoors and in observatories.

II. In which paragraph do you find the answer?

1. Does astronomy help us find new ways of communication?
2. Can amateurs study astronomy?
3. What is Stonehenge?
4. What is the most important instrument in the planetarium building?

III. Knowing What and Why

1. Jodrell Bank
    a. has the vault that stores telescopes.
    b. is the city where Stonehenge is located.
    c. is a mountain with a telescope on it.
    d. is an observatory.
2. The observations of astronomers all over the world
    a. contradict each other and confuse us.
    b. are put together for better understanding.
    c. are sent to Washington, D.C.
    d. are projected on the planetarium dome.
3. An observatory
    a. needs only a good telescope.
    b. needs many instruments.
    c. must be on a mountain in pure air.
    d. is usually part of a university.
4. In a planetarium building, the motions of the moon are
    a. projected on a dome-shaped screen.
    b. impossible to demonstrate.
    c. photographed as they take place.
    d. magnified and colored.

IV. Find the Connection

1. The astronomer is to the stars as the ________ is to living things.
2. The ________ is to the planetarium building as the telescope is to the observatory.
3. The lens is to the telescope as the ________ is to the microscope.

V. True or false? Explain.

1. Meteorologists do not have much interest in the work of astronauts.
2. All telescopes use lenses.
3. Gravitation and gravity really mean the same thing.
4. There is a need for physicians at the Kennedy Space Center.

VI. For the Collector

Write to The National Aeronautics and Space Administration, Washington, D.C. Ask for *free* booklets about their work.

VII. For the Science Reporter

Read about the life of any one of the scientists below and write a report.

Tycho Brahe
Johannes Kepler
Galileo
Nicolaus Copernicus
Percival Lowell

4

TARGET
What are the instruments of the astronomer?

The Tools of the Astronomer

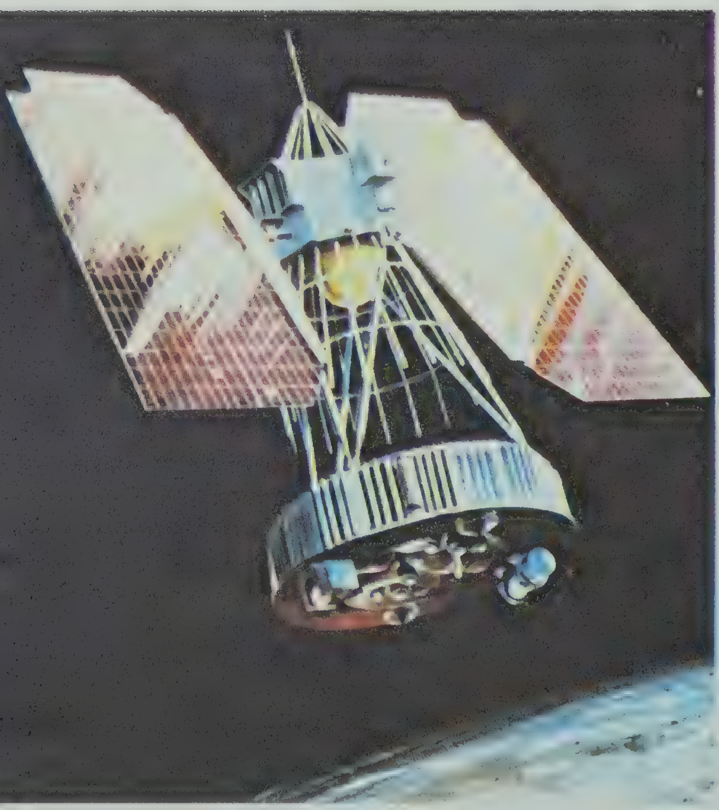


Fig. 28–1

The satellite, NIMBUS-4, gathers data high up in the atmosphere. Why does a satellite not fall down?

1. LOOKING FROM HERE . . . GOING THERE

The most important job in astronomy is still observation from the earth. However, we have recently been able to leave the earth to go into the upper atmosphere and into outer space.

In your study of weather, you became acquainted with helium-filled balloons that carried the *radiosonde* into the atmosphere. The national weather service has man-made satellites in space to send back information by radio signals. Now, space capsules, some of which carry astronauts, are beginning to gather data from outer space.

2. WHAT ARE WE REALLY OBSERVING?

When we study the skies, we are really looking at the light given off by radiation from the sun and other stars.

We study the path of this light and its reflection by nonluminous planets, our moon and other satellites. We study the speed of the radiation and what it does to the atmosphere, to chemicals and to living things. For a complete picture, we study the rest of the *electromagnetic spectrum.*

3. WINDOWS INTO SPACE

Look back at Fig. 5–1. This chart shows you that the energy given off by our sun forms many rays arranged in an electromagnetic spectrum. Fig. 29–1 is the same chart drawn in a different way.

You will recall that we see only the visible light rays in the middle of the spectrum. The rays to the left, the ultraviolet rays, X rays and gamma rays, are blocked out by the atmosphere. On the other side of the visible light, there are the infrared rays, also blocked out. Then there is a wide band of radio waves that do come through.

In other words, we have two "windows" into space: we have the *optical window* and the *radio window.* It is mostly through these two windows that we study astronomy and aerospace science.

YOU NOW KNOW

- We study space and its bodies by observation on the earth and by balloons, satellites and space capsules away from the earth.
- Most of our studies are done through those rays in the electromagnetic spectrum which are not filtered out.
- We study space and astronomy through the optical window and through the radio window.

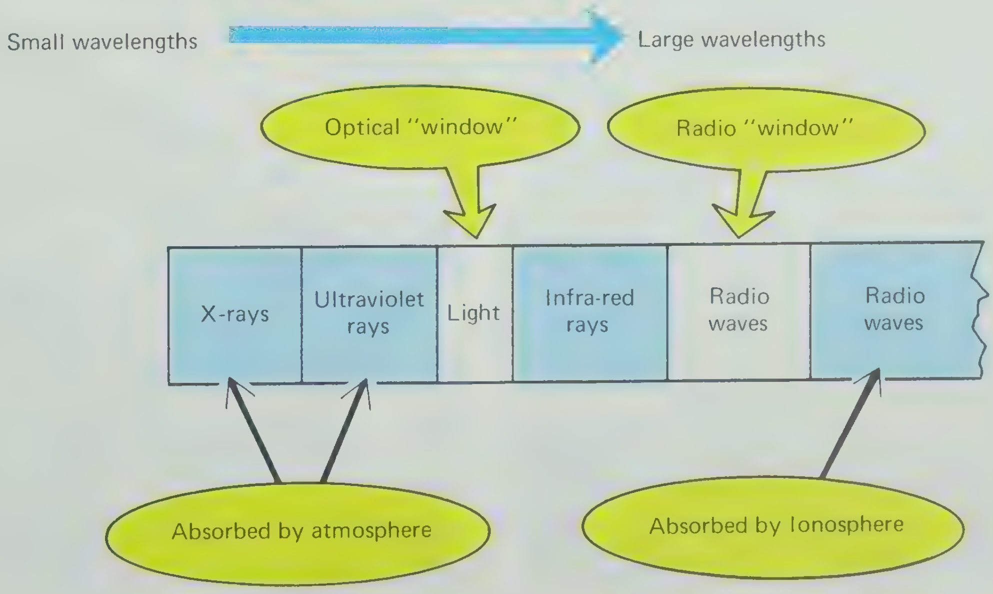


Fig. 29–1

Two windows, the optical and radio "windows," allow us to study space and its bodies.

4. TELESCOPES WITH LENSES

What can we use to look through the optical window? Of course! We use optical instruments—instruments designed for use with light. We use our eyes, optical telescopes, and spectroscopes.

Early telescopes, such as Galileo's telescope, were the *refracting* type. This type of telescope is made of a long tube with a convex (curved outward) lens at each end. The lens closest to the sky is called the *objective lens.* It is very large so it can gather light from far away places. This lens refracts (bends) the light to form a small, bright image. Then the eye lens, or eyepiece, magnifies this image still more and brings it to the eye.

The largest refracting telescope in the world is in the Yerkes Observatory, in Wisconsin. Its lens is 102 cm in diameter. Its tube is over 18 m long. It can bring a star about 4000 times closer to the eye.

5. TELESCOPES WITH MIRRORS

It is hard to make large lenses; it is easier to make large mirrors. The Mt. Palomar telescope is a reflecting telescope (see Fig. 30–2). It uses a giant concave (curved inward) mirror which has a diameter of 510 cm. How does it work? Let's do a simple demonstration to find out.

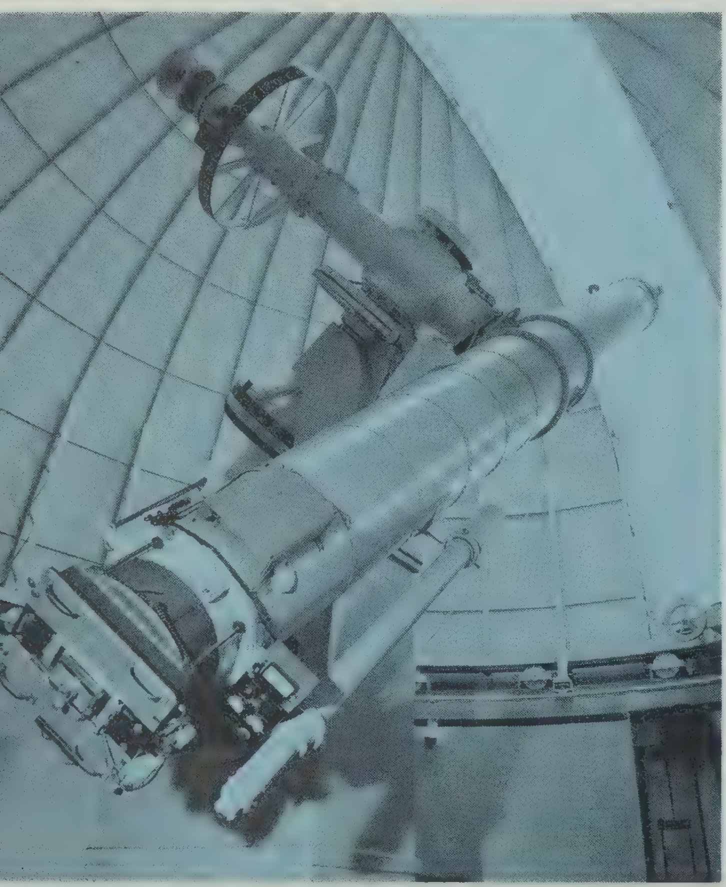


Fig. 30–1

This is a refracting telescope. It is in the U. S. Naval Observatory in Washington, D. C. Its lens is 66 cm in diameter.

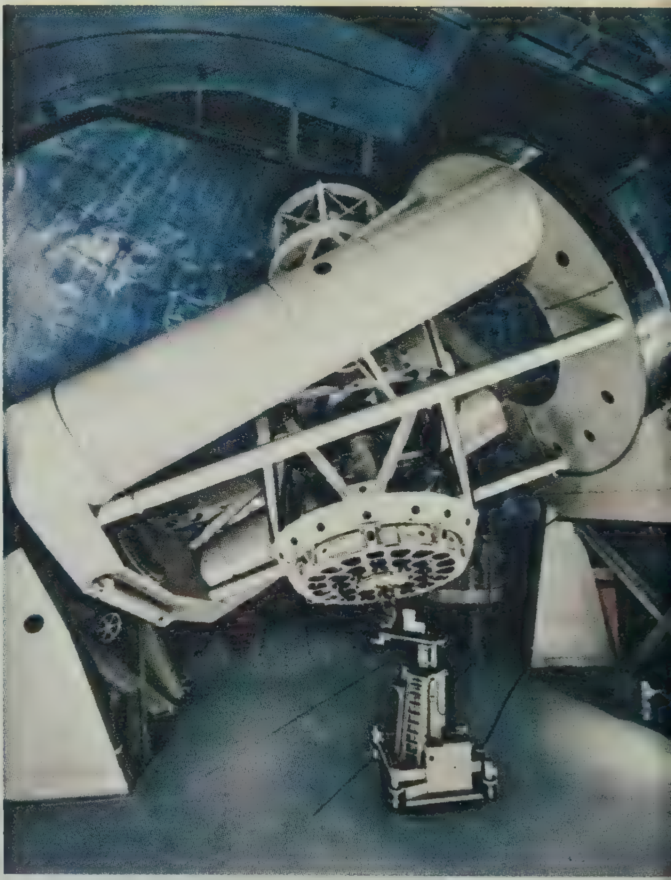


Fig. 30–2

This is the Mt. Palomar telescope. It is a reflecting telescope whose mirror is 510 cm in diameter.

DO AND DISCOVER

Investigation 1: How do concave mirrors work in a telescope?

Set up a concave shaving mirror on a table in front of a window. Catch the image of a tree, flag pole or telephone pole in the mirror. Move the mirror until the image is projected on the wall. Now, with the aid of a convex lens, enlarge the image for your eye. (Fig. 31–1A). What do you see?

In the reflecting telescope, the light from the stars (Fig. 31–1B) enters the tube. The light is gathered by the concave mirror and reflected upward. A real, upside-down image is formed. A flat mirror directs the image out of the tube through a convex lens into a side tube. The observer views the star from the side.

OPTICAL TELESCOPES
Refracting ⟶ With Lenses
Reflecting ⟶ With Mirrors

6. LISTENING TO OUTER SPACE

Clouds, rain and smog sometimes block our optical window. High up in space "star dust" blocks our view. Our optical telescopes become less useful. It is for this reason that astronomers turned to the radio window.

The sun, some planets, our moon and the stars give off radio waves. Radio waves are also given off by stars we cannot see even with optical telescopes. Of course, we cannot hear radio waves. We must detect them with special receivers. These are the *radio telescopes* which were invented in 1931.

A radio telescope is really a big radio receiver. The most important part of the radio telescope is the antenna.

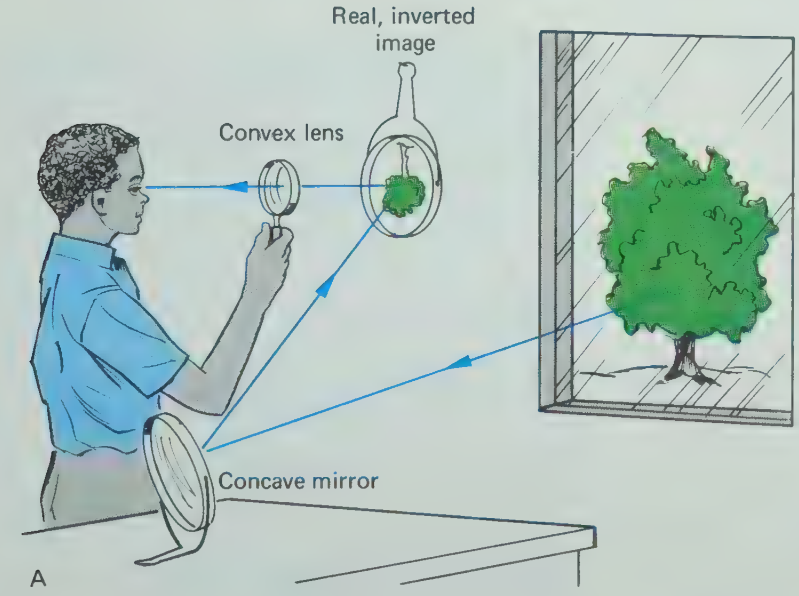


Fig. 31–1A

Try this easy demonstration.

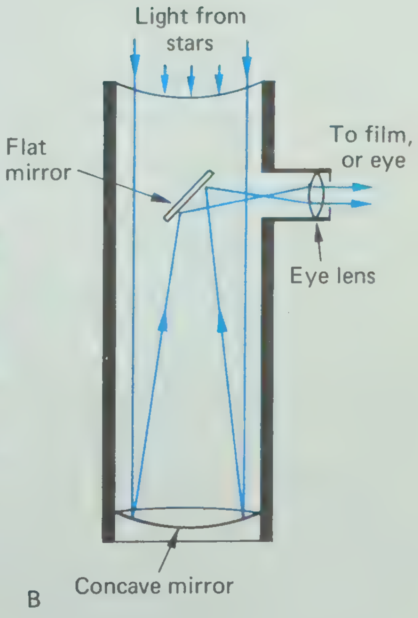


Fig. 31–1B

Trace the path of light rays in this reflecting telescope.

The antenna is in the middle of a huge concave reflector, shaped like a soup bowl. The reflector gathers the radio waves at the antenna which are then sent to a receiver. The receiver changes the radio waves to electrical waves. The electrical waves operate a pen in a recorder and the waves are drawn on a roll of paper. In this way, we can locate stars that we can't actually see. The chart (Fig. 32–1) shows how the radio telescope works.

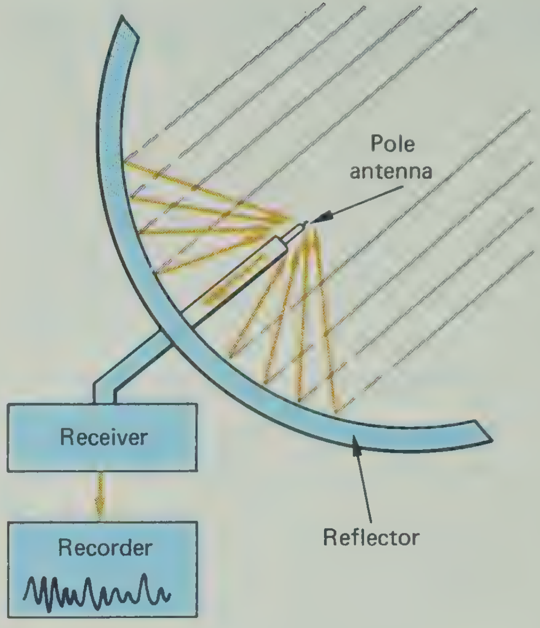


Fig. 32–1

Look at the picture of the radio telescope in Fig. 25–2, page 25. The reflector can be tilted to any height. The antenna can be turned in any direction. This diagram shows the scheme of the radio telescope and the path of the radio waves.

YOU NOW KNOW

- There are reflecting, refracting and radio telescopes.
- A radio telescope finds planets and stars by the radio waves that they give off.
- A radio telescope can be used day or night. Reflecting and refracting telescopes can only be used at night.

7. OTHER TOOLS FOR ASTRONOMERS

In your earlier study of physics and chemistry, you learned that when materials get very hot, they glow. This glow is called INCANDESCENSE (in-kan-DES-ens). When incandescent light or white light is sent through the prism of a *spectroscope*, a band of colors is formed. We call this band a *spectrum*. Every material gives off a different wavelength of light which refracts a different color on the spectrum. The spectroscope can, therefore, be used to identify glowing elements in the sun and stars. We shall come back to this later.

Another tool used by astronomers

TOOLS OF THE ASTRONOMER

Instrument	*Use*
Telescopes	Optical: Reflecting (mirrors) Refracting (lenses) Radio: (radio waves)
Chronograph	Time
Transit	Angles
Photometer	Light Intensity (brightness)
Thermocouple	Temperature
Spectroscope	Elements

is the CHRONOGRAPH (KRO-no-graf) which is a recording clock. The TRANSIT (TRAN-zit) is an instrument used to measure angles. You may have seen a road SURVEYOR (sur-VAY-ur) use this instrument to measure the angles of a new road. To measure the brightness of light, an astronomer would use a PHOTOMETER (fo-TOM-i-tur). To measure temperature of a star, the astronomer uses a THERMOCOUPLE (THERMO-kup-ul).

UNDERSTANDING WHAT YOU HAVE READ

I. What are the two main ideas in Chapter 4?

1. Astronomy studies the behavior of light from stars and planets.
2. The radio window helps us catch radio waves.
3. Spectroscopes study elements in the sun.
4. The astronomer uses many tools; telescopes are the most important.

II. In which paragraph do you find the answer?

1. What instrument measures time for the astronomer?
2. What is a radio telescope?
3. How does visible light enter our atmosphere?
4. Where is the largest refracting telescope in the world?

III. Knowing What and Why

1. The contribution of man-made satellites is that we now
   - a. get readings from outer space.
   - b. can send messages from the moon.
   - c. collect cosmic rays.
   - d. have a new window into space.
2. Refracting telescopes produce images that are
   - a. enlarged and upside down.
   - b. small, bright and upside down.
   - c. blurry, small and in full color.
   - d. mostly useless.
3. A radio telescope is really a device that
   - a. picks up waves from outer space.
   - b. sees reflections of the earth.
   - c. analyzes spectra.
   - d. picks up the effects of infra-red rays.
4. The Mount Palomar telescope uses
   - a. a mirror that refracts.
   - b. a lens that reflects.
   - c. a lens that refracts.
   - d. a mirror that gathers light.

IV. Understanding the Diagrams

In Fig. 32–1,

1. The radio waves are received first by the ________.
2. The radio waves are reflected by the ________ to the ________.
3. Which part amplifies (makes stronger) the waves?

In Fig. 31–1B,

4. What is the job of the convex lens?
5. How can you get a brighter image?

V. Explanation, Please

1. If X rays are given off by the sun, why do we not see them?
2. Why is the light coming through the optical window white?
3. How does a photometer differ from a spectroscope?
4. How can a surveyor's instrument be used by an astronomer?

VI. For the Home Scientist

You can make a simple refracting telescope.

Materials:

2 cardboard tubes, one that fits into the other.

2 convex lenses: one large thin one (1), one small thick one (2).

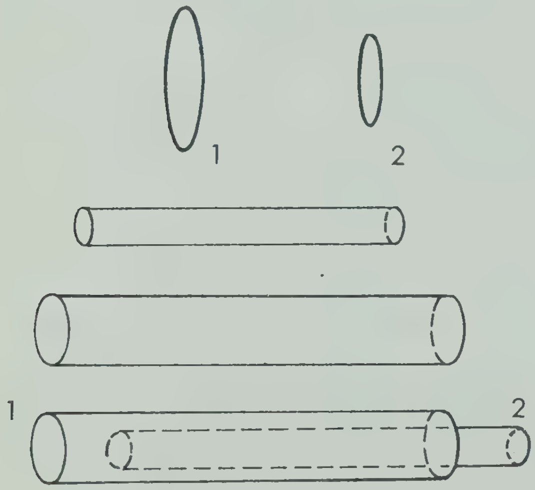


Fig. 34–1

Construction:

Fasten the objective lens (large lens) at one end of the large tube. Use modeling clay to keep it in place. Fasten the eyepiece or small lens (2) at one end of the smaller tube. Slide the smaller tube into the larger one. When put together, the lenses should be at opposite ends of the tube.

Use:

Use your telescope at *night* to sight the stars and moon. Sliding the tubes helps focus for clearer images.

VII. For the Music Lovers

Make a list of all the songs (classical and popular) in which there appear the words, *star*(s), *moon, sun.* Compare your list with those made by your friends. Consult your music teacher.

VIII. For the Poetry Lovers

Make a list of poems which deal with stars, moon, sun or planets. Arrange to read one to your class. Is the poet also accurate in a scientific way? Ask your teacher of English to help you.

5

TARGET
How are the bodies in the universe arranged?

The Solar System

1. IN DAYS OF OLD

When ancient men looked up into the sky, they were able to see shining spheres: the sun, the moon and the stars. As they watched from day to day and through the nights, they saw that these bodies changed their positions. It seemed to the men that the skies were circling overhead as the earth stood still. Of course, the earth seemed flat and the heavens round. The earth seemed to be the center of the universe. The earth stood still and the bodies in the skies revolved around it. This scheme of the universe was taught by the great Greek scientist, Ptolemy. He completed his work in the year 150 A.D.

2. WHAT DID THEY SEE?

Even in ancient days before telescopes, there were some who watched more carefully. They counted the risings and settings of the sun; they noted the movements of the moon. Some people even counted the stars they could see and wrote down their positions. Among the stars, people noticed five special bright "stars" that wandered in and out, back and forth, among the other stars. They were named the PLANETS (PLAN-its) from the Greek word meaning *wanderer.* The five planets moved at different speeds. The fastest was called MERCURY (MUR-kur-ee), after the speedy messenger of the gods. A planet of shining beauty a little slower than Mercury was called VENUS (VEE-nus). The planet which was often red, was named MARS (MARZ), after the god of war. The largest was called JUPITER (JU-pit-er), the father of the gods. The slowest planet was called SATURN (SAT-urn), after the god of agriculture.

Sometimes, man looked at groups of stars and imagined he saw shapes, usually of animals. The Big Bear, the Little Bear, the Crab are a few examples. Such groups of stars are called CONSTELLATIONS (kon-stuh-LAY-shuns).

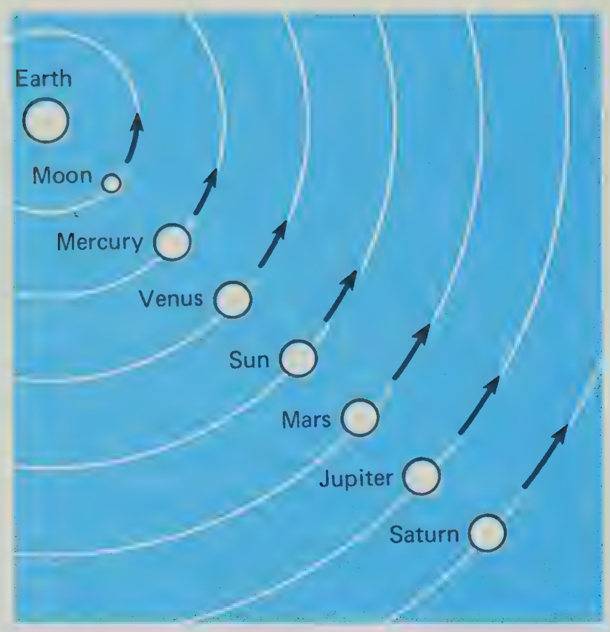


Fig. 36–1

This was the scheme of the universe as Ptolemy saw it. The earth was at the center. Five planets were known.

3 A NEW CENTER FOR THE UNIVERSE

From your study of history, you will remember that from about 400 A.D. to about 1000 A.D. there was a time called the *Dark Ages*. In this period, very little new learning took place. The science of astronomy also seemed to have fallen asleep.

It was not until 1543, that Nicolaus Copernicus, a Polish scientist, published a new theory about the universe. In this scheme, the sun is at the center and the planets move (revolve) around the sun. Suddenly, many unanswered questions could be solved.

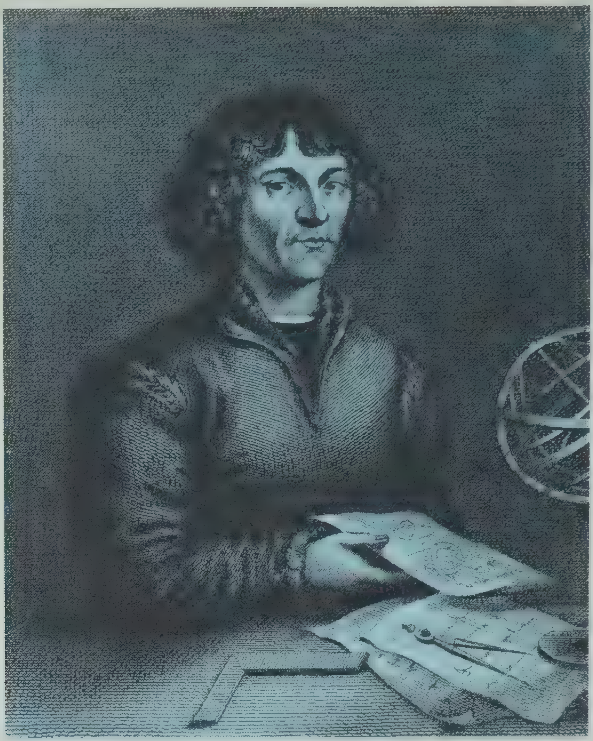


Fig. 36–2

Nicolaus Copernicus (1473–1543) was the author of a new idea of the universe. What was that idea?

4. THE BIG PLAN

Before the days of the telescope, the sun, the five visible planets, the moon and the 3000 visible stars were thought to be all there was in the skies. That was all of it; that was the universe. Today, we know that the universe is much bigger.

If you sit in a ball park, you can see some faces across the field that are only groups or outlines. So, too, with stars. Some of the visible stars are so clear you can see them as single stars. Some are not clear, but you can see their light. Instead of seeing stars, you see "clouds of light". These "clouds of

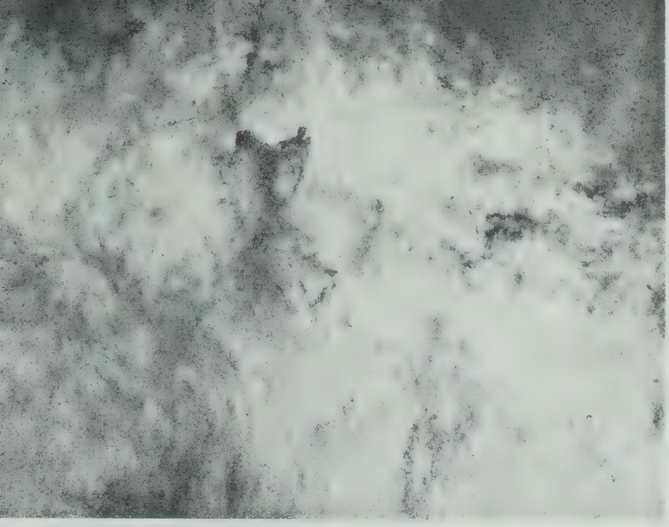


Fig. 37–1

The Milky Way is thought to have 100 billion stars. It is spiral shaped. The best time to see it is on a clear summer night.

light" were given the colorful name, the *Milky Way*.

Our sun is only one star in the Milky Way. The Milky Way forms a large system or group. Such a system of stars with dust and gases in space is called a GALAXY (GAL-ax-ee). Are there other galaxies? Yes, but we can never know how many. There are three other galaxies that we can see with the naked eye. There are billions of other galaxies, some of which we can see with good telescopes. Most, however, are too far away to see.

YOU NOW KNOW

- The old idea of the earth-centered universe has been replaced with the modern idea of the sun-centered universe.
- The universe is made of galaxies of stars.
- Our planet belongs to the sun which is one star in a galaxy called the Milky Way.

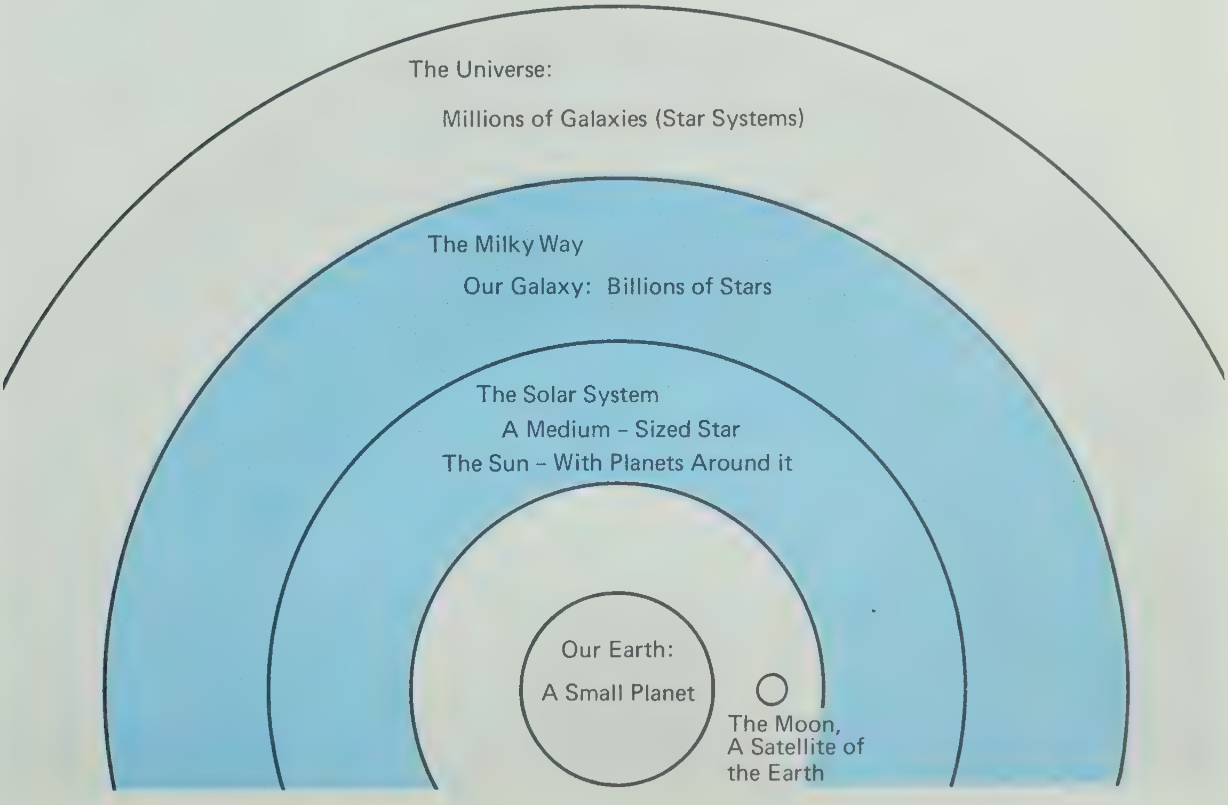


Fig. 37–2

When we think of our universe, we must think big. The universe is so big, we can hardly imagine its size. (Note: the sizes in the diagram are not exact.)

5. OUR SOLAR SYSTEM

Now let us get back to Copernicus's idea. In his day, the whole of the universe was what we now call the solar system. As we said before, the sun is a medium-sized star. Revolving around the sun, are its nine planets. Some of the planets have satellites such as the earth's moon; others do not. The sizes of planets, their paths in the skies and many other things are known about them. We shall study the planets in detail in a later chapter. Our solar system also has about 50 000 smaller bodies called PLANETOIDS (PLAN-i-toyds) or ASTEROIDS (AS-tur-oyds). You will see in the chart, Fig. 38–1, that most of these seem to stay between Mars and Jupiter.

6. ALWAYS MOVING

The most important law of the space bodies, is that nothing stands still. Everything in the universe is moving. The Milky Way is moving. Our sun, like all the other stars, is moving. The planets move around the sun, all in the same direction. If you look back at Fig. 38–1, you will see that each planet follows a definite path or *orbit*. Notice that the path is not a circle. It is a "flattened" circle,

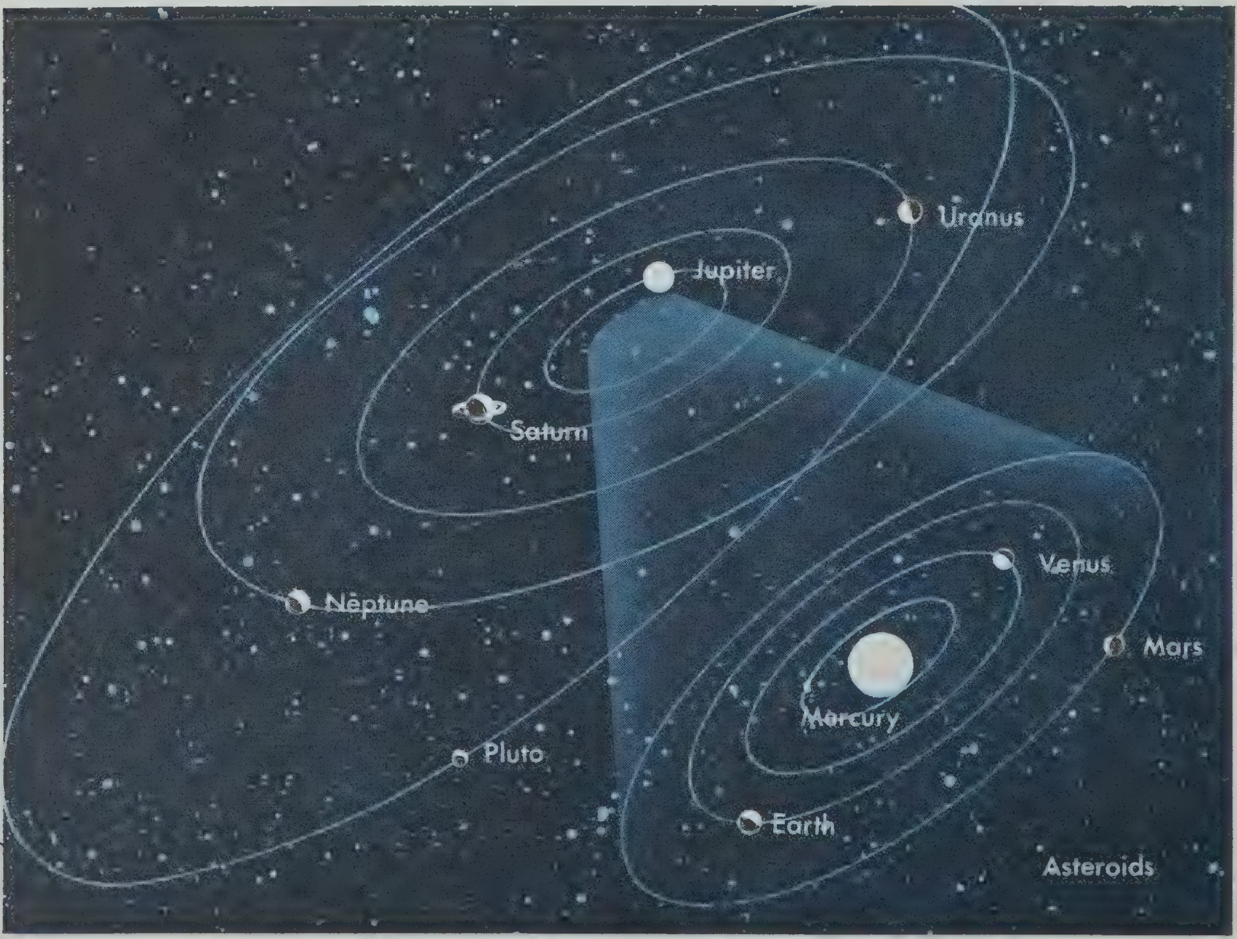


Fig. 38–1

Our solar system has nine planets. Which five can be seen with the naked eye? What is the shape of the orbits?

called an ELLIPSE (ee-LIPS). And, of course, our satellite, the moon, moves in orbit around the earth.

7. WHY DO THEY STAY IN ORBIT?

For our answer, we go back to Sir Isaac Newton. His Law of Gravitation told you that every body in the solar system attracts every other body. But the earth's gravitation, you say, will attract the moon so hard that it should fall smack against the earth! And the earth should go crashing into the sun! But you must remember the *Law of Inertia*. This law states that objects in steady or constant motion continue to move in steady motion unless they are stopped by an outside force. The planet "tries" to move in a straight line; the sun's gravitation attracts it. The two forces combine to keep the planet moving in an ellipse. So, it stays in orbit.

8. HOW DID IT START?

There are many theories that explain how the universe was formed. In fact, some scientists believe that new bodies are constantly being formed. One theory explains it this way: outer space is filled with clouds of gases. These clouds and dust condense to form dense materials. It is almost like forming a snowball out of soft snow. When the materials become very dense, chemical and physical changes take place and a star is formed. This theory and other evidence make it reasonable to believe that new stars are being born all the time.

YOU NOW KNOW

- Our solar system has a star (the sun) at its center; nine planets around it; with satellites such as our moon around some of the planets.
- All bodies in space keep moving because of inertia and stay in elliptical orbits by the force of gravitation.
- Bodies in the solar system are believed to have been formed by condensation of hot gas clouds to form dense masses.

UNDERSTANDING WHAT YOU HAVE READ

I. What are the two main ideas in Chapter 5?

1. The solar system in which we live is in the Milky Way.
2. The universe consists of many galaxies, or groups of stars.
3. Ptolemy's theory is still believed to be true today.

4. You can only see a few planets without a telescope.

II. Explanation, Please . . . answer in one or two sentences.

1. What do we call groups of stars?
2. Which planets are visible with the naked eye?
3. What is the Milky Way?
4. How does gravitation explain a moving universe?

III. Knowing What and Why

1. Ptolemy was able to see
   a. Mercury and Venus.
   b. Mercury and Pluto.
   c. Saturn and Neptune.
   d. Neptune and Pluto.
2. Copernicus's great contribution was that he
   a. located three more planets.
   b. proved Eratosthenes correct.
   c. developed the idea of the galaxy.
   d. placed the sun at the center of the universe.
3. That the earth stays in orbit is best explained by
   a. the magnetic effect of the sun.
   b. the Law of Gravitation.
   c. the forces of outer galaxies.
   d. electromagnetic pull.
4. The newest idea is that our solar system
   a. was torn from a distant galaxy.
   b. was formed from clouds of gases.
   c. came from the sun.
   d. came from a volcano in a distant star.

IV. Choose the word that does not belong with the other three. Explain your answer.

Example: basketball, football, chess, track. The answer is *chess.* (Three are athletic games; chess is not).

1. stars, Proxima Centauri, sun, Venus
2. Venus, Earth, Moon, Mars
3. galaxy, Milky Way, star system, asteroids
4. eclipse, orbit, revolution, inertia

V. True or false? Explain.

1. The earth moves around the sun.
2. The earth moves in an elliptical orbit.
3. No more new bodies are being formed in space.
4. We can see other galaxies with the naked eye.

VI. Fill in the missing letters. Get the name of a President. Answer is on Page 54.

E L L 2 P S E
G 5 L A 10 Y
3 11 8 S T E L L A T I O 12
O 1 B 9 T
B R A 4 E
A S T E 6 O I 7

– – – – – – –   – – – – –
1 2 3 4 5 6 7   8 9 10 11 12

6

TARGET
What do we know about the members of the solar system?

The Solar System Family

1. LOOKING BACK. . .

Look back at Fig. 38–1. The "big plan" of our solar system shows the sun surrounded by nine planets. The nine planets revolve in orbits around the sun. Notice carefully that each orbit is not a perfect circle. It is an ellipse. Later, we shall look at ellipses more carefully. Some questions people ask about the planets are shown below.

- 1. What are their sizes?
- 2. What are their masses and densities?
- 3. How fast do they move?
- 4. Do they have life on them?
- 5. Can we get to them?

2. WHAT DO WE KNOW ABOUT THE PLANETS?

We already know that planets do not glow. They shine by reflected sunlight. Planets do not twinkle, like stars. Their light is steady. Mars, Jupiter and Saturn can be seen all night. But Mercury and Venus are seen only just after sunset, or just before sunrise. When people talk of the *evening star*, they really mean the planet Venus. Venus is also called the *morning star* because it appears in the east just before sunrise.

Planets differ in size. Mercury is the smallest and Jupiter is the largest. Jupiter's diameter is about eleven times the size of the earth's diameter. Venus is the closest in size to the earth.

3. PLANETS REVOLVE . . .

Planets revolve in orbits around the sun. They are visible only by the reflected light of the sun. Since planets are at different distances from the sun, their speeds of revolution are different. Mercury is the fastest. It is nearest to the sun. Mercury completes its revolution around the sun in only 88 earth-days. Pluto, the most distant planet from the sun, takes about 248 earth-years to revolve around it.

4. . . . AND PLANETS ALSO ROTATE

Each planet spins or rotates around its own axis. Jupiter makes one complete turn on its axis once every 9 h and 50 min. A single rotation of Venus takes about 243 d, almost a full revolution of the earth (365 d). Since the planets' masses and diameters differ, there is a different gravitational pull on objects on their surfaces. The masses of objects on the planets' surfaces, compared to the earth, is shown in Fig. 42–2.

5. DAYS AND YEARS ON PLANETS

Each part of the planet faces the sun through part of its rotation. It faces away from the sun through the rest of its rotation. Like the earth, each planet has night and day. A planet "day" is the time it takes for the planet to make one complete rotation on its axis. Each planet revolves around the sun in different positions. Each planet, in a full revolution, has a planet year.

ROTATION → planet day and night
REVOLUTION → planet year
PLANET YEAR → 1 revolution of any planet
EARTH YEAR → 1 revolution of earth

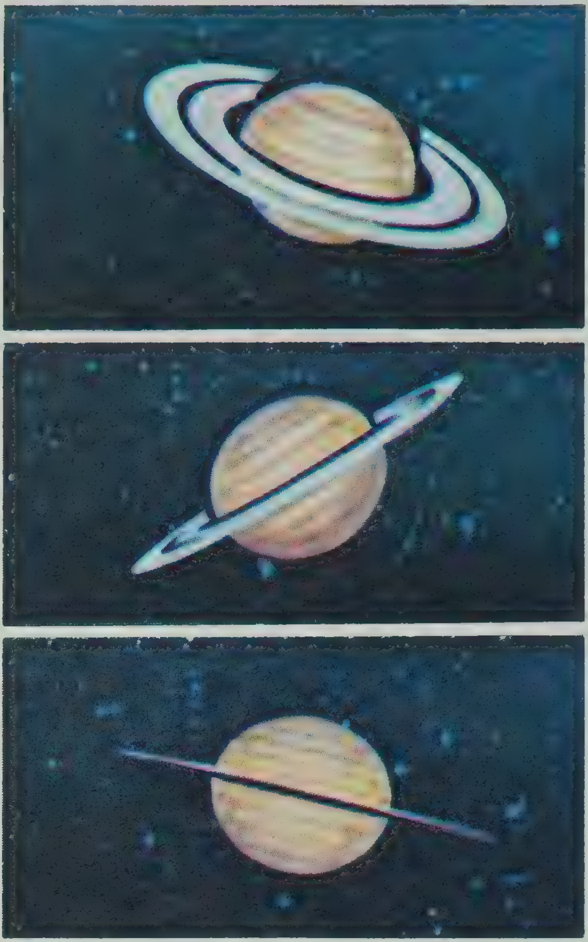


Fig. 42–1
Can you recognize this planet?

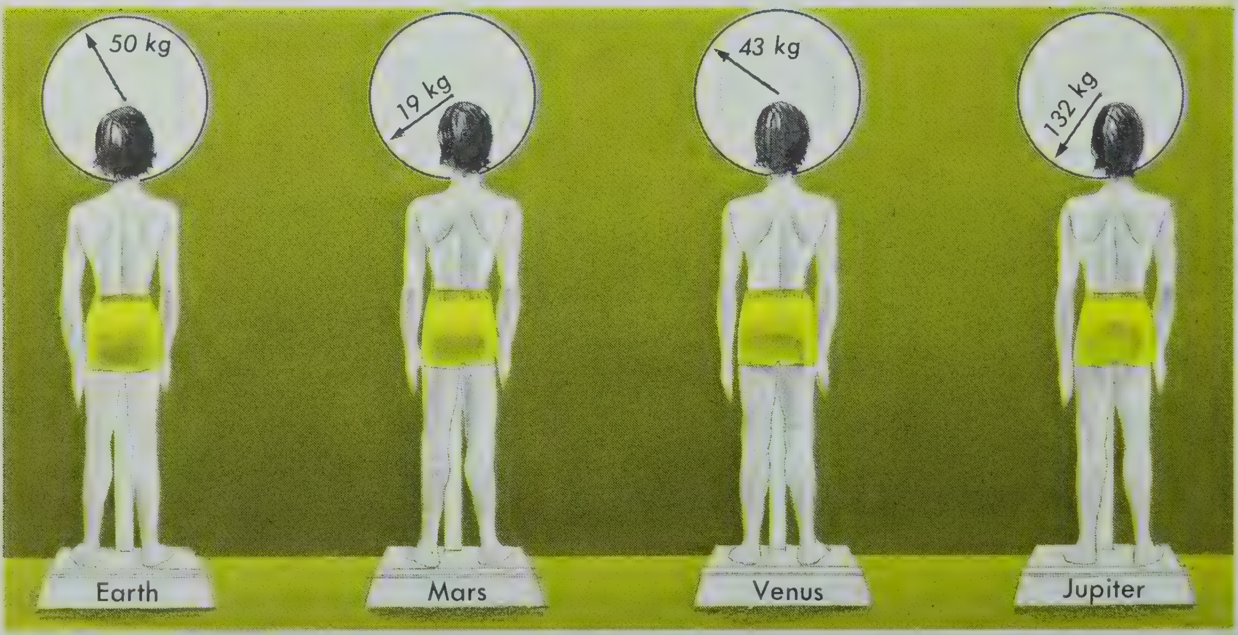


Fig. 42–2
How much would you weigh on each of these planets?

6. SATELLITES OF THE PLANETS

The earth has a companion in space. It is called a *satellite*. You know it as our moon. Mercury, Venus and Pluto show no satellites. The chart (Fig. 46–1) shows that some of the planets have satellites. Saturn also shows four "rings" around it. These rings are thought to be made of frozen chunks of methane, ammonia and probably small particles of dust.

YOU NOW KNOW

- Nine planets revolve around the sun.
- Planets differ in mass, density, speed and orbit.
- Planets shine by reflected light and they have days, nights and years.

7. THE SURFACE OF THE PLANETS

What is the surface of planets like? A look at the chart (Fig. 46–1) will show you the average temperature on the surface. As you can imagine, we do not have all the answers. But we do know that Venus has an atmosphere that is mostly carbon dioxide. Mercury has no known atmosphere. Scientists have observed "caps" at the poles of Mars. They believe these are ice caps, made mostly of solid carbon dioxide. The reason for the red color of Mars is still unknown. Recent photographs show that the surface of Mars has volcanic craters and canyons. The matter of which planets are made is probably the same as the earth or moon.

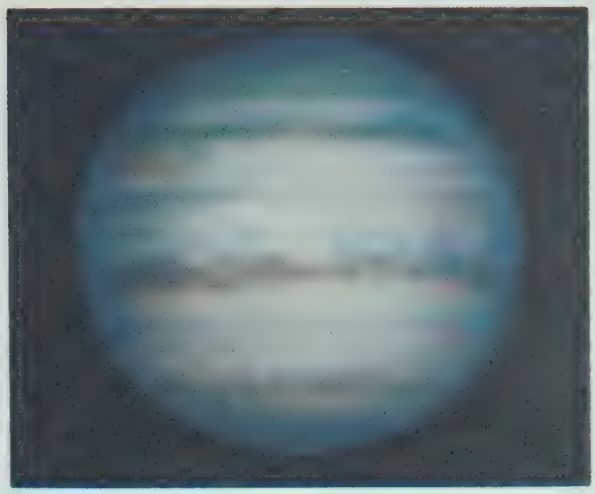


Fig. 43–1

This is a picture of the planet Jupiter.

8. IS THERE LIFE ON OTHER PLANETS?

Life, as we know it, needs an atmosphere. It needs oxygen and water. It needs a temperature which is not too high and not too low. On this basis, we can say that the kind of life we know probably does not exist on the other planets.

At one time, some people believed that the regular "lines" on Mars were canals built by intelligent people. Latest information from orbiting unmanned satellites shows that there is very little water vapor in Mars' atmosphere. At this time, our evidence leaves doubt about life on Mars.

9. THE LITTLE LEAGUE OF THE SOLAR SYSTEM

Earlier, we mentioned the *asteroids*. About 50 000 of these are in orbit between Jupiter and Mars. They are also called *planetoids*.

In 1986, you will be treated to a great show in the sky. A COMET

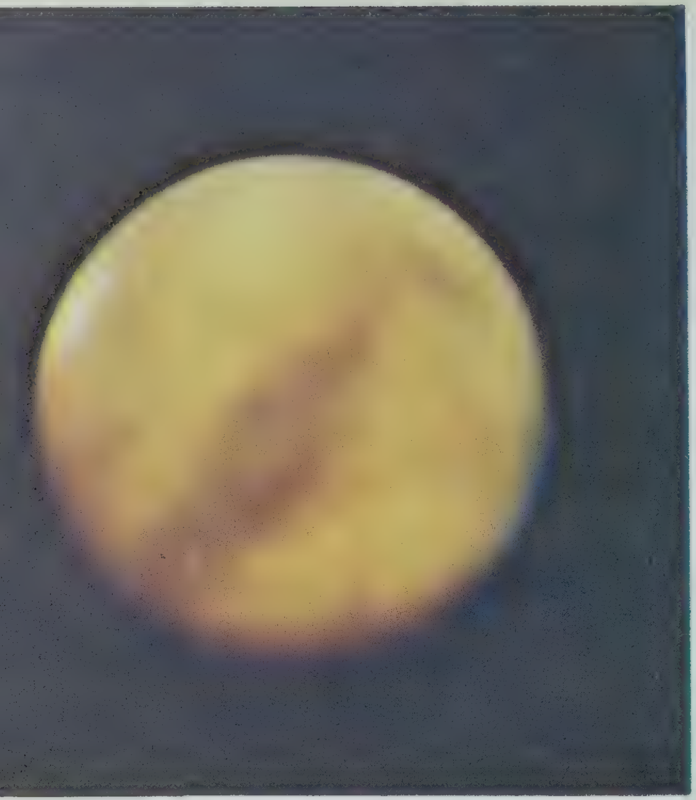


Fig. 44–1

Mars has polar "caps." What do scientists believe they are made of?

(KOM-it), called Halley's Comet will revisit our skies. A comet is a mass of fine dust and ice particles which stick together to form a "head" and a "tail." Comets travel in orbits in various speeds and great distances. Many comets are known and their visits can be predicted. Halley's Comet was first seen in the year 240 B.C. The last time it was seen was in 1910.

In March 1973, a new comet was discovered. It was named KOHOUTEK (ko-HOO-tek) after its discoverer. It was speeding through the solar system at about 113 800 km/h. It reached its closest point to earth (about 120 million kilometres) around Christmas. It was not as bright as had been predicted. Later it looped around the sun. It is believed that this caused the ice to change to vapor. The comet then became surrounded by a cloud of hydrogen, five million kilometres wide. It disappeared into outer space and will not be seen again for 75 000 years. Still want to see a comet? Wait till 1986!

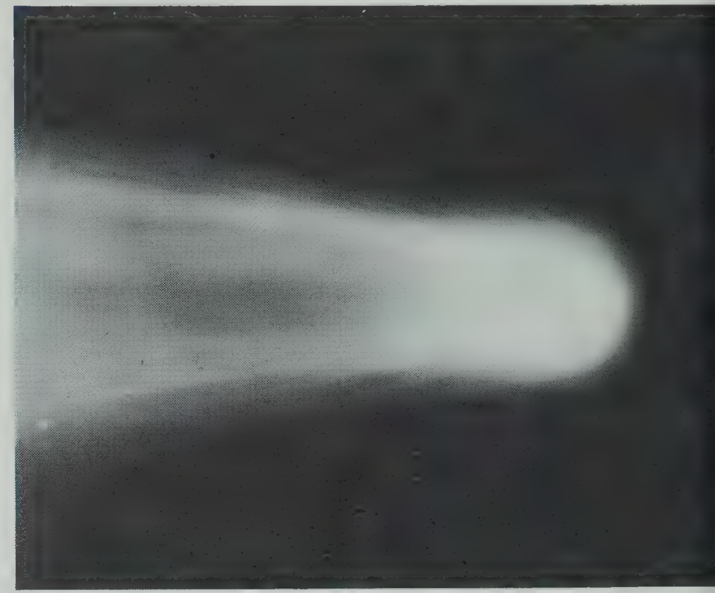


Fig. 44–2

Halley's Comet will revisit our skies again in 1986. It will be a great show!

10. MAKE A WISH ON A "SHOOTING STAR"

Sometimes, on a clear summer night, you can see flaming objects "shooting" through the sky. They are called "shooting stars." Some people quickly "make a wish."

Your wish may or may not come true. One thing is sure; you have not seen a star at all. The flaming object is a huge chunk of stone with iron and nickel in it. As it whizzes through the air, the heat of friction makes it glow. You are really looking at a METEOR (MEE-tee-or). Some meteors burn completely in the atmosphere and we never see them again. Other meteors land on the earth and cool off quickly.

What is left of the meteor on the earth is a chunk of metal or stone called a METEORITE (MEE-tee-uh-rite). Meteorites vary in size from small pebbles to huge stones. Some meteorites, when they hit the earth, actually dig a deep hole.

11. SPACE PROBES TO THE PLANETS

The modern method for studying planets is through *space probes.* A space probe is made by an unmanned satellite, orbiting in space, traveling around the planets. In Chapter 23, you will read more about this.

What new ideas about planets have we gotten? Here are a few samples.

ABOUT MARS: Mars has high winds (185 km/h); the clouds are made of water vapor and dust; there are volcanoes and deep canyons; the South Polar ice cap may have some frozen water. In the early afternoon, its temperature is about +27°C.

ABOUT MERCURY: There are craters like on the moon and Mars; the surface is pockmarked; there is a very weak magnetic field; high density compared to earth.

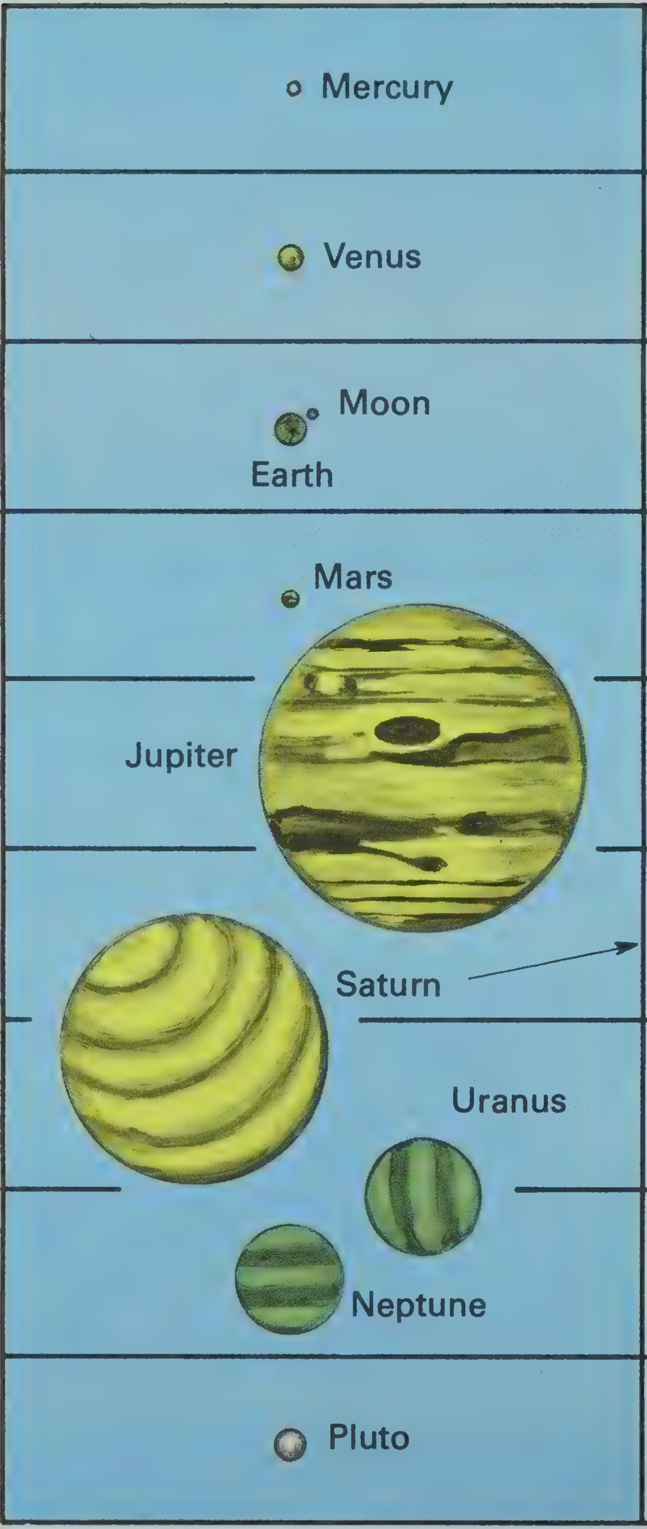
ABOUT VENUS: Venus is dry (no water); the atmosphere is nearly all CO_2, producing a greenhouse effect; there are no radiation (Van Allen) belts; no magnetic field; Venus rotates in a clockwise direction, unlike the other planets.

ABOUT JUPITER: Jupiter has a powerful magnetic force, 40 times as powerful as the earth's; rays (from Van Allen belts) are 10 times as powerful as those of earth—enough to kill every man, woman and child; temperature is about the same during night and day; its atmosphere has helium; at the poles, it is gray; towards the equator is blue, yellow, orange, pink; four of its twelve moons rotate clockwise. The Great Red Spot is 48 000 km long and 13 000 km wide; it darkens redder about every 30 years.

Fig. 45–1

This meteorite was a meteor when it came flaming through the atmosphere. Some astronomers believe it may have been torn from a comet.

TABLE OF PLANETS



Planets	Diameter in km	Millions of km from Sun	Average Surface Temperature
Mercury	4880	58	371°C. (sunlit side)
Venus	12 104	108	427°C
Earth Moon	12 756	150	14°C
Mars	6 789	228	−23°C
Jupiter	142 800	777	−133°C
Saturn	120 000	1426	−163°C
Uranus	51 800	2879	−207°C
Neptune	49 500	4494	−184°C
Pluto	5982	5894	−213°C

Fig. 46–1

Pluto, which is in the outermost orbit, moved inside of Neptune's orbit in 1969 for 40 years. In the year 2009, it will return to the outermost orbit.

Period of Rotation	Period of Revolution Earth Days or Years	Number of Satellites	Mass Compared to Earth	Atmosphere Contains
59 d	88 d	0	1/20	none
243 d**	225 d	0	4/5	nitrogen (N_2) argon (Ar) carbon dioxide (CO_2) water (H_2O)
23 h, 56 min 4 s	365.24 d	1	1.0	nitrogen (N_2) oxygen (O_2) water (H_2O) carbon dioxide (CO_2) and others
24 h, 37 min 23 s	687 d	2	1/10	carbon dioxide (CO_2) water (H_2O) atomic oxygen
9 h, 50 min 30 s	11.86 years	12	318 X	hydrogen (H_2) ammonia (NH_3) methane (CH_4)
10 h 14 min 0 s	29.46 years	10* and 4 rings†	95 X	hydrogen (H_2) ammonia (NH_3) methane (CH_4)
10 h 49 min 0 s	84.02 years	5	14 X	hydrogen (H_2) methane (CH_4)
16 h (?)	164.8 years	2	17 X	hydrogen (H_2) methane (CH_4)
6 d 9 h	248.9 years	?	?	?

* 10th satellite discovered in 1967

** In a clockwise direction

† 4th ring discovered in 1969

UNDERSTANDING WHAT YOU HAVE READ

I. What are the two main ideas in Chapter 6?

1. Your mass on Venus decreases because of low gravitation.
2. Nine planets form part of the solar system family.
3. We know many things about the planets.
4. Shooting stars may destroy the earth.

II. In which paragraph do you find the answer?

1. What is the shape of the orbit of the planets?
2. Why do we not see comets often?
3. What is a space probe?
4. How long is a day on a planet?

III. Knowing What and Why

1. A meteorite is
   - a. the tail of a comet.
   - b. the remains of a meteor that hits the earth.
   - c. one of the rings of Saturn.
   - d. the smallest of the asteroids.
2. Life on Mercury is ruled out because
   - a. we've never gotten an answer to our radar.
   - b. it has a weak magnetic field.
   - c. there is no atmosphere.
   - d. shooting stars keep crashing on its surface.
3. In general, the speed of a planet around the sun
   - a. is the same each day.
   - b. is slower than the earth.
   - c. depends on its mass and distance from the sun.
   - d. is controlled by presence or absence of atmosphere.
4. The last three planets discovered by man are
   - a. Mercury, Venus and Pluto.
   - b. Pluto, Uranus and Neptune.
   - c. Neptune, Venus and Mars.
   - d. Mars, Mercury and Pluto.

IV. Name the planets described below.

1. It shows icy caps at its poles.______
2. Closest to the sun. ___________
3. Next orbit past the earth. ______
4. Rings around it. ___________
5. Over 300 times the size of the earth. ___________
6. Evening star. ___________
7. Day almost like earth's day. ______
8. Red color. ___________
9. Atmosphere of dust and CO_2. ___________
10. No satellites. ___________

V. True or false? Defend your answer.

1. Canals on Mars were built by Kohoutek.
2. Shooting stars are bigger than the sun.
3. The Great Red Spot is an orbiting Russian Satellite near Mars.
4. Another name for *asteroids* is *planetoids*.

VI. For the Imaginative Writer

Write a short story using the following title,
"My Trip to Mars and Back."

VII. Start a Clipping Collection

In the next few years exciting discoveries will be made in space travel. Buy a scrapbook. Keep your eyes open for news items on space exploration. Paste the clippings into the book and record the dates. Someday your own children will enjoy reading these first reports of space conquest.

7

TARGET
What do we know about the sun?

The Sun Is a Star with Energy

1. APOLLO, GOD OF THE SUN

It is not surprising that ancient people worshipped the sun as a god. Of course, the sun meant warmth, light, youth, beauty and cheer. The Greeks called the god of the sun Apollo (a-POL-o). They also built temples for the sun and worshipped Apollo. They may not have had much scientific knowledge about the sun, but they certainly realized that the sun controlled their lives.

2. WHAT IS THE SUN?

The sun is a huge mass of hot, incandescent gases in the shape of a sphere. It is about 150 000 000 km from the earth. Light from the sun travels at the speed of 300 000 km/s. It takes 8.3 min for the sun's light to reach our earth.

The best evidence we have shows that the sun's outside (surface) temperature is about 5500°C. That would make the surface about 55 times hotter than boiling water. Of course, such temperatures are even hard to imagine.

The sun appears to be golden during the day, and sometimes red at sunset. Focus the sun through a convex lens on a piece of white paper. You will see its real color. It is a pale yellow.

3. NUMBERS, PLEASE . . .

The *statistics* (collection of numbers) about the sun are interesting and tell us many things. The sun's *diameter* (distance across the sphere) is 1 392 688 km. Its *circumference* (distance all around the sphere) is 4 344 700 km. By careful arithmetic, we learn that the sun's mass is equal to 333 400 earth masses. The sun's gravity is about 28 times greater than that of the earth. It is interesting to compare the sun with the earth and with the moon. You can fit about 1 000 000 earths into the sun.

BODY	DIAMETER	CIRCUMFERENCE
Sun	1 392 688 km	4 344 700 km
Earth	12 800 km	40 250 km
Moon	3 480 km	10 800 km

4. WHAT IS INSIDE THE SUN?

As we said before, the sun consists of very hot gases glowing to incandescence. Since everything is made of matter, we want to know which gases (elements) are in the sun.

Examination with spectroscopes shows that about 80% of the sun is made of hydrogen and about 18% of helium. There are also small amounts of copper, nickel, iron, calcium, sodium and aluminum. About 70 elements found on earth are found on the sun.

5. JOURNEYS OF THE SUN

Ptolemy's scheme, you remember, had the earth standing still and the sun moving. When Copernicus's new theory replaced the Ptolemy idea, some people then thought that the sun stood still. But we now know that that isn't true, either. In the first place, the sun turns on its own axis. The earth makes a full spin in about 24 h. The sun takes about 25 *earth days* to rotate at its equator. What a long period of daylight!

But the sun not only spins on its axis, it also moves in space. It keeps

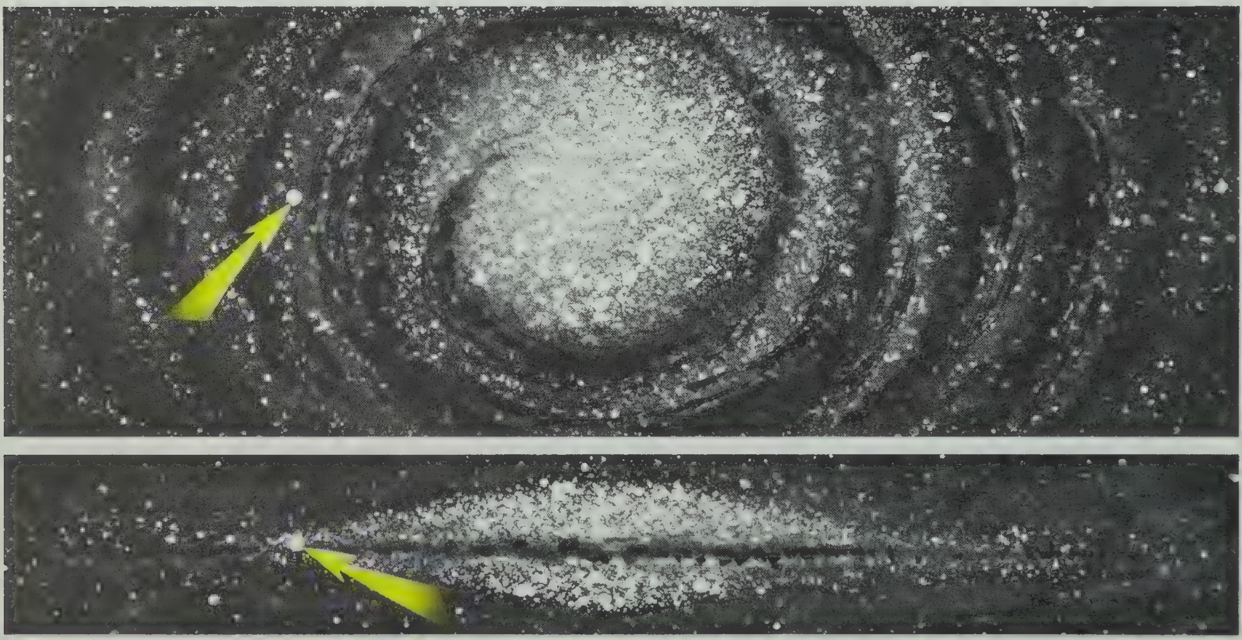


Fig. 50–1

The sun moves along in the Milky Way. The sun is 33 000 light-years from the center. (It takes 33 000 years for light to travel from the sun to the center of the Milky Way.)

circling together with its neighboring stars. How fast is it going? It goes about 240 km/s around the center of the Milky Way! The orbit of the sun is very large, so it takes about 200 million years to complete one revolution. The sun moves with its entire galaxy, the Milky Way.

YOU NOW KNOW

- The sun is a sphere of hot gases with temperatures from 5500°C on the surface, to 16 600 000°C inside.
- About 70 elements found on earth are also found in the sun. Hydrogen makes up about 80%; helium about 18%.
- The sun rotates on its axis. It also revolves in the Milky Way.

6. OBSERVING THE SUN'S APPEARANCE

Observing usually means looking. *WARNING: Never look directly at the sun!* Your eyes contain convex lenses that focus the sun's rays to a point on the retina. This can cause burns and permanent damage. Sunglasses are *not* enough! Looking at the sun through binoculars or a telescope is extremely dangerous. You can be blinded.

Astronomers observe the sun through special filters and by taking special photographs. Another safe way, good for amateurs, is called *projection*. In this method, the telescope projects the light onto a screen.

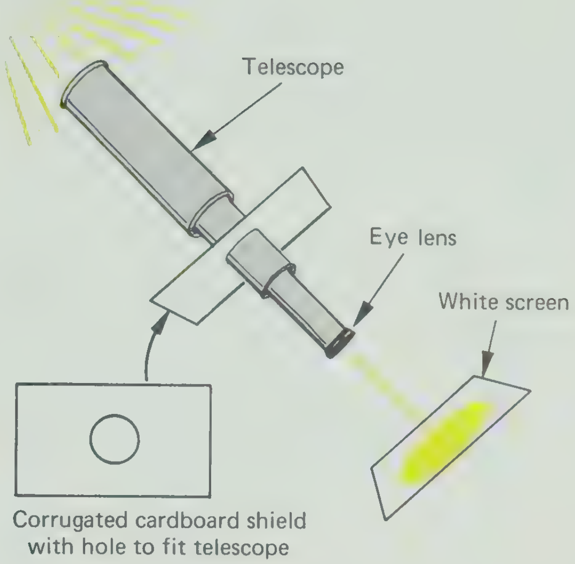


Fig. 51–1

The telescope is set through a hole in a piece of corrugated cardboard. The circle of the sun is projected on a sheet of white paper.

7. STUDYING SUNLIGHT WITH A SPECTROSCOPE

You have learned before that a prism can separate the white light of the sun to form the color spectrum. When you analyze the same light with a spectroscope, the spectrum has a series of dark lines. The dark lines are caused by hot, incandescent gases in the atmosphere of the sun. In your chemistry work, you learned that each element has its own color when it glows. By matching colors, scientists can identify elements in the sun.

In 1869, a scientist studying the sun with a spectroscope, found a yellow line that did not match any element on

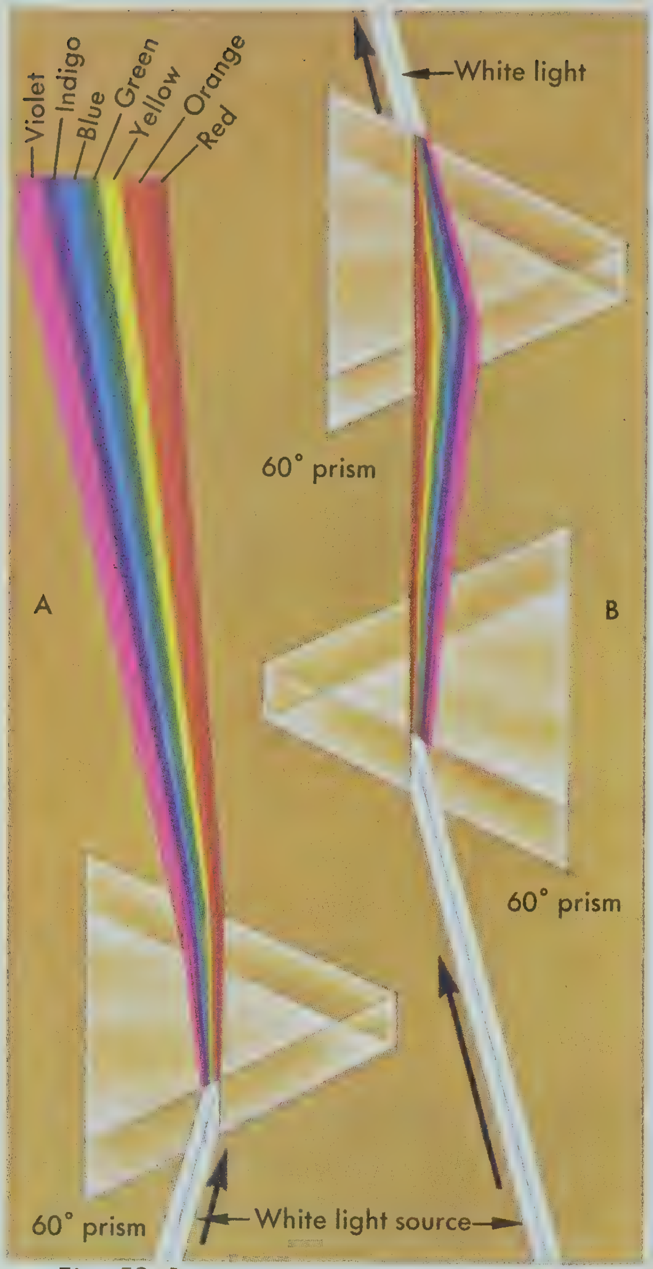


Fig. 52–1

White light from the sun forms a spectrum.

earth. He called this element *helium* after helios, the Greek word for sun. In 1895, the gas helium was found on earth, in an oil field in Texas.

8. THE APPEARANCE OF THE SUN

Imagine that we could slice the sun with a knife like we slice an apple. The inner section is the *core*, the hottest part of the sun. The core is surrounded by hot gases, the *convection zone*. Then comes the sphere of light at the surface. This is the part of the sun that we see. It is called the PHOTOSPHERE (FO-to-sfeer). The dark spots that you see near the sun's surface are *sunspots*. We shall discuss these in our next chapter.

Surrounding the photosphere is a layer of gases that glows red. This is the CHROMOSPHERE (KRO-mo-sfeer). Spectroscopes show it to be about 16 100 km thick. Sometimes hot streams of gases shoot out into space from the chromosphere. When the moon shades the sun to form a total solar eclipse, it is possible to see the sun's "atmosphere" called the CORONA

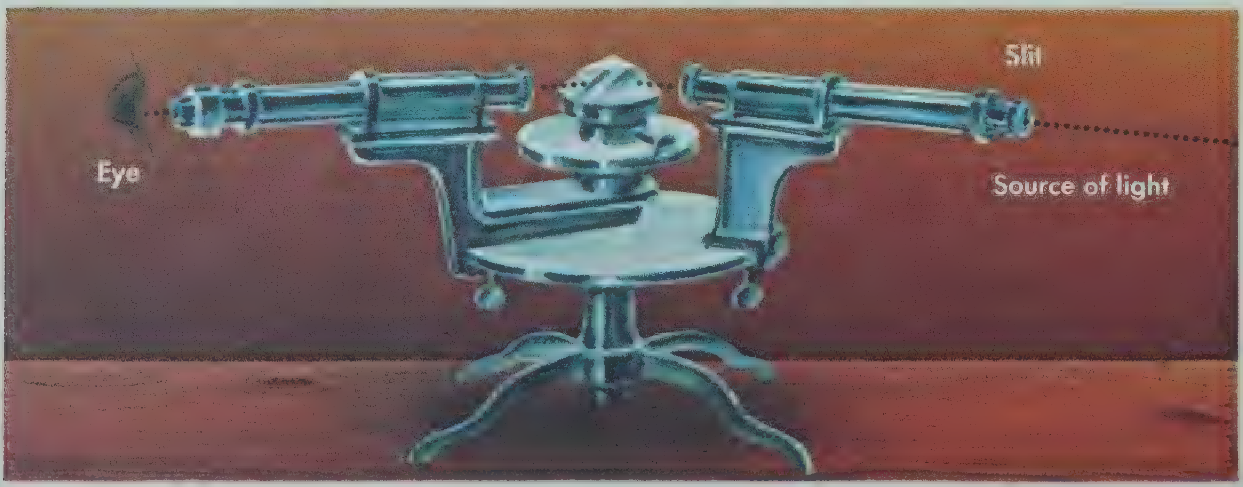


Fig. 52–2

The spectroscope analyzes light from the sun to identify elements found in the sun. Which element was found in the sun before it was found on earth?

(kuh-RO-nuh). It cannot be seen all the time because of the bright light of the sun.

YOU NOW KNOW

- The safest way to observe the sun is by projection.
- A spectroscope can show which elements are in the sun's hot gases by their colors.
- The sun is made of several layers of hot gases which have different temperatures.
- The part of the sun we usually see is the photosphere.

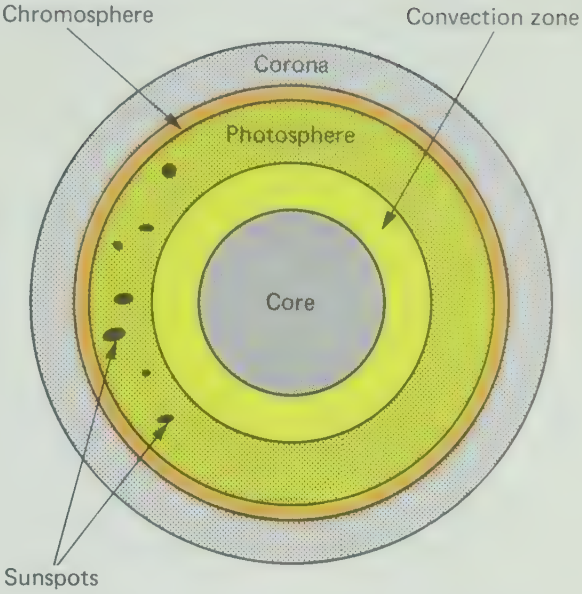


Fig. 53–1

Each sphere or area of the sun has hot gases at different temperatures.

UNDERSTANDING WHAT YOU HAVE READ

I. What are the two main ideas in Chapter 7?

1. You must never look at the sun directly.
2. The sun is made of hot gases.
3. The sun is a moving body in the Milky Way.
4. The sun has definite compounds in it.

II. In which paragraph do you find the answer?

1. How hot is it on the sun?
2. Whose gravity is stronger, the earth's or the sun's?
3. How long does it take for the sun to rotate on its axis?
4. How can we find out if the element lithium is on the sun?

III. Knowing What and Why

1. The area of the sun seen only during an eclipse is the
   a. galaxy.
   b. corona.
   c. photosphere.
   d. core.
2. The diameter of the sun is
   a. 365¼ times that of the moon.
   b. 93 000 000 times as big as the earth.
   c. less than 100 times that of the moon.
   d. more than 100 times that of the earth.
3. The spectroscope is best used with materials which are
   a. colloidal.

   - b. incandescent.
   - c. soluble.
   - d. neutralized.

4. Sunspots are found in the
   - a. photosphere.
   - b. chromosphere.
   - c. atmosphere.
   - d. lithosphere.

IV. Understanding the Diagrams

1. Look at Fig. 52–2. Read the title. Now write a new, different title, that will also be correct.
2. Do the same for Fig. 50–1.

V. For the Amateur Scientist

If you own, or if you can borrow a telescope, set it up as shown in Fig. 51–1. Draw the sun as it is projected at the same time for 10 days. Note the changes.

VI. For the Science Reporter

Write a report on the work of Sir Joseph Lockyer, the discoverer of helium.

VII. Match the words in Column A by choosing the correct words from Column B.

A	B
1. core	a. temperature of sun
2. 300 000	b. 25% of atmosphere
3. helium	c. sun god
4. spectrum	d. band of colors
5. Apollo	e. speed of light
6. system of stars	f. galaxy
7. hydrogen	g. inner layer
8. total solar eclipse	h. element first found in the sun
	i. shows corona
	j. 80% of the sun's gases

ANSWER TO PUZZLE V, PAGE 7

1. **T**emperature, 2. **E**nergy, 3. **L**ithosphere, 4. **E**lectron, 5. **S**tar, 6. **C**ore, 7. **O**xidation, 8. **P**lanet, 9. **E**ngine

ANSWER: **TELESCOPE**

ANSWER TO PUZZLE VI, PAGE 40

2 5 10 3 11 8 12
1. ELLIPSE, 2. GALAXY, 3. CONSTELLATION,

1 9 4 6 7
4. ORBIT, 5. BRAHE, 6. ASTEROID

1 2 3 4 5 6 7 8 9 10 11 12
ANSWER: **RICHARD NIXON**

TARGET
How does the sun affect the earth?

8

The Sun's Energy Controls the Earth

1. LOOKING BACK . . .

The radiant energy of the sun travels across 150 000 000 km in space. It reaches our earth in 8.3 min.

Look back at Fig. 5–1, the electromagnetic spectrum. Study it carefully and you will again see the different kinds of rays in that spectrum. The ones most important to us are the visible light rays, the infrared heat waves, and the communication-radio waves.

2. THE SUN KEEPS US IN ORBIT

The sun's gravitational pull keeps our earth in orbit. If it were not for this attraction, the earth would fly off into space. Because we revolve around the sun, the amount of sunlight which reaches us in a given part of the earth changes from day to day. The slant of the rays is different. In this way, our seasons are born. We shall study time and the seasons in Unit III.

3. WHERE DOES THE SUN GET ITS ENERGY?

Most of the sun is hydrogen and helium. The core of the sun has an intense temperature (about 16 600 000°C).

The theory that fits the facts is that the hydrogen is being changed to helium. Where? In the core, by intense heat. To change hydrogen to helium, there must be a change in the nuclei of these atoms. Such a reaction is called THERMONUCLEAR (THERMO-NEW-klee-ur). When we put these facts together, we have the answer to the above paragraph question.

THERMO
(heat)
+
NUCLEAR
(of the nucleus)

THERMONUCLEAR REACTION
Atoms are changed to new atoms by heat.

4. HYDROGEN TO HELIUM

Now let's look at the chemistry of a thermonuclear reaction. A hydrogen nucleus has the atomic mass 1.008. The helium nucleus has a mass of 4.003. As four hydrogen nuclei fuse (combine) to form one helium nucleus, some matter seems to disappear. How does this answer the paragraph question?

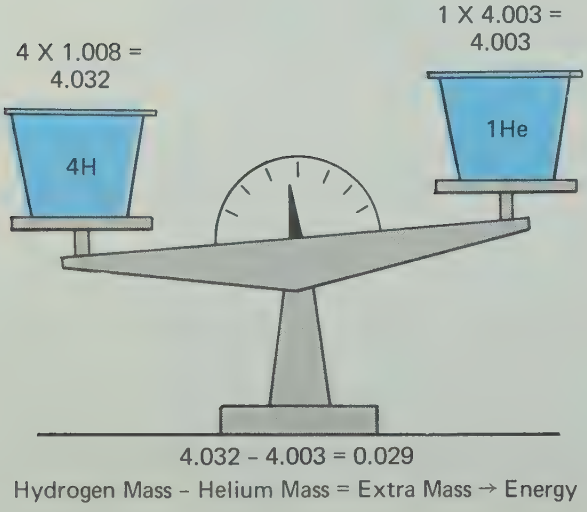


Fig. 56–1

There is a change of matter. What has happened to it?

Look at Fig. 56–1. In this scale, you see that the four hydrogen nuclei weigh more than one helium nucleus. There seems to be a loss of matter. Where did this matter go? You are right. This "lost" matter has become energy. And what a lot of powerful energy! The process is called *thermonuclear fusion*, or just *nuclear fusion*. Nuclear fusion is the process used in the hydrogen bomb. As you know, the hydrogen bomb has a powerful force that can cause terrible destruction. In the sun's core, nuclear fusion goes on all the time at a controlled rate. Hydrogen fusion is the source of most of the sun-energy.

NUCLEAR FUSION: → Hydrogen fusion forms helium → Hydrogen Bomb

YOU NOW KNOW

- The sun controls the movements of the earth.
- The sun is the source of most energy on the earth.
- Energy is released in the core of the sun by thermonuclear fusion of hydrogen to form helium.

5. SUNSPOTS AND SUN STORMS

Look back at Fig. 51–1 (solar projection apparatus). If you were to make drawings of the sun from day to day, and year to year, you would discover that the surface of the sun is covered with spots. The spots move along with the sun. Take a football and paste several pieces of masking tape across the face. Now spin the ball slowly. The "spots" will reappear on the other side.

Astronomers who have watched sunspots for years have noticed that their size and number keep getting larger. This change builds up for a period of about 11 years. We call this the *sunspot cycle*. The next high period will be in 1981. During the high period, there will be a great increase in static on radios. Compasses will not register accurately, which means that the earth's magnetism will be affected.

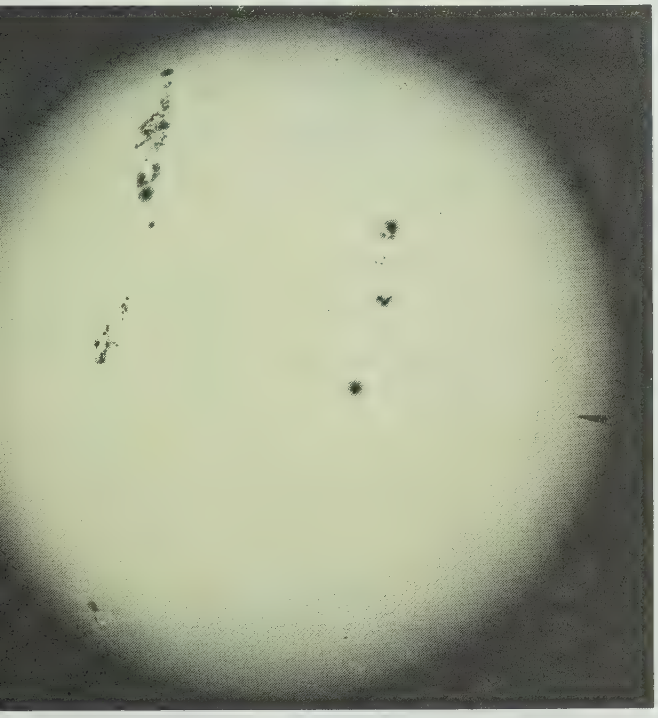


Fig. 57–1

Sunspots are cooler gaseous regions of the sun which appear darker and may be as wide as 161 000 km.

What are sunspots? They are darker, cooler areas in the photosphere. However, they are not cold, nor solid. Because these gaseous areas are cooler than the rest of the photosphere, they look dark. Around the sunspots, there are *solar flares*. These flares are thought to be showers of charged particles hurled out into space.

6. THE ENERGY ARRIVES ON EARTH

On earth we receive only one-two billionth of the sun's energy. This may seem small, but it is really a great deal. Fortunately for us, most of this energy is absorbed in the earth's atmosphere. If all of the rays were to reach us, life would be impossible. About 32 km above our earth, there is a thick layer of gas called OZONE (OH-zohn). Ozone absorbs most of the ultraviolet rays. These rays, you will remember, can cause serious skin and eye burns.

After this "filtering" process, the sun's energy that reaches us is either visible (white) light, or infrared (invisible heat) rays.

7. THE SUN CONTROLS OUR WEATHER

Radiant sun-energy turns to heat after it touches matter. Visible light rays are changed to infrared rays to produce heat. Temperatures in the upper atmosphere vary from very cold to very hot. At 160 km above sea level, the temperature is 260°C. At 400 km, it climbs to 1650°C.

Changing temperatures in the atmosphere set up convection currents which cause winds. Changing temperatures produce rain, snow and hail. Therefore, the weather on earth is controlled by the sun.

8. PHOTOSYNTHESIS, NOW AND LONG AGO

The visible light provides the energy for the manufacturing of food by green plants. This process, PHOTOSYNTHESIS (FO-to-SIN-the-sis), could not take place without light. Animals feed on plants. Human beings depend on plants and animals for food. In addition, photosynthesis also provides oxygen for living things. Do you remember the formula for photosynthesis?

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2 \uparrow$$

But that is not the whole story. Let us review the story of fossil fuels. A *fossil*, you may remember, is the remains of living things which died millions of years ago. Giant ferns turned to coal about 325 million years ago.

Deep in the earth, beneath several kinds of rocks, man has uncovered PETROLEUM (puh-TRO-lee-um), which is a mixture of hydrocarbons. About 500 million years ago, microscopic plants and animals lived, died and decayed to form the *crude oil*. Petroleum and coal were both formed through photosynthesis with energy from the sun. Today, millions of years later, the potential energy of fuels does our work for us.

Fig. 58–1

Deep in the earth and on the continental shelf fossils have formed petroleum. The fossils, once alive, got their energy from the sun.

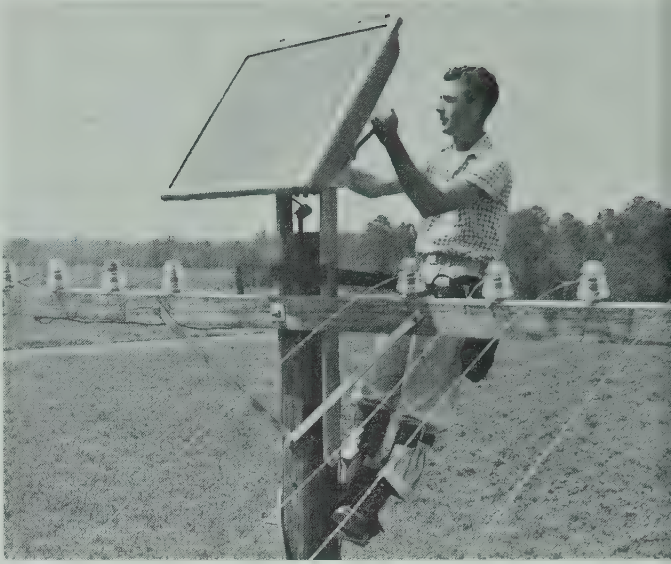


Fig. 58–2

The day when we get energy directly from the sun is not far off. Already, solar batteries are being used to provide heat and energy.

YOU NOW KNOW

- Sunspots are cooler areas of the sun which appear as dark spots in the photosphere.
- Only part of the sun's energy reaches us on earth in the form of visible light and infrared heat waves.
- The sun's heat controls our weather.
- Light provides energy for photosynthesis of food.
- Coal and petroleum were formed by sun energy millions of years ago.

UNDERSTANDING WHAT YOU HAVE READ

I. What are the two main ideas in Chapter 8?

1. The sun's energy is like that of an atomic bomb.
2. The sun controls most energy on the earth.
3. Radio static comes from sunspots.
4. Most energy in the sun comes from thermonuclear fusion.

II. Explanation, Please . . . answer in one or two sentences.

1. How much of the sun's energy reaches earth?
2. How did the sun create energy to run a taxi?
3. What process creates helium on the sun?
4. Where does hydrogen fusion take place in the sun?

III. Knowing What and Why

1. The energy of nuclear fusion in the sun comes from
   a. left over energy.
   b. left over mass.
   c. splitting helium atoms.
   d. combining of hydrogen atoms.
2. Sunspots are
   a. hot spots with strange elements.
   b. dark, cooler spots in the photosphere of the sun.
   c. new stars being born.
   d. planetoids leaving the sun.
3. Most of the cosmic rays, gamma rays and X rays are
   a. vaporized in the photosphere.
   b. absorbed in the atmosphere.
   c. refracted by earth.
   d. changed to ozone.
4. Weather on earth is controlled by the sun's energy mostly
   a. by ozone.
   b. through gamma rays.
   c. by condensation of star dust.
   d. by heat changes.

IV. Choose the better of the two answers in parentheses.

1. Sunspots are in the (corona, photosphere).
2. Atomic fusion takes place in (the core of the sun, the atomic bomb).
3. Photosynthesis uses (chemical, radiant) energy.
4. Ancient fern plants formed (fossil coal, fossil petroleum).
5. The earth stays in an orbit around (the sun, the planet Pluto).

V. Number, Please . . .

To what does each number refer? *Do not write in this book.*

1. 8.3 min ____________
2. 300 000 ____________
3. 150 000 000 ____________
4. 12 800 ____________
5. 40 200 ____________
6. 11 years ____________
7. 16 600 000°C ____________
8. The year, 1970 ____________

VI. For the Science Reporter

1. Read about sunspots. Write a report.
2. In an encyclopedia, look up Sir Joseph Lockyer, British astronomer. Read about his discovery of helium.

9

TARGET
What do we know about the stars?

The Stars, Near and Far

1. LIKE THE STARS IN HEAVEN

What do people mean when they say "like the stars in heaven"? Well, they may mean beauty. They may mean brightness. They may mean very large, countless numbers. All of these are true of the stars in our skies.

Stars, like our own sun, are masses of hot gases whirling in space. They glow in different colors depending on their elements and temperatures. As in our sun, atomic fusion goes on all the time. Stars belong to "clubs" called galaxies. Galaxies have billions of members.

2. LET'S COUNT THE STARS

Silly, isn't it? Where can you begin? Where can you end? How do you know you're not counting twice? And yet, astronomers have been able to make good estimated counts and even draw maps of the skies.

About 3 000 stars are visible to the naked eye. Of course, as you keep using better and better telescopes, you see more and more stars. It is estimated that the 510 cm Mt. Palomar telescope in California brings billions of stars into view. Some stars are very easy to locate because they form a pattern in the sky. We shall see some of these patterns in Paragraph 8.

3. WHAT KINDS OF STARS?

Stars can be described by four simple words: *size*, *color*, *brightness* and *temperature*. How do we find out about the stars? As usual, we depend on careful observation, the use of special instruments and mathematics.

How big are the stars? The smallest

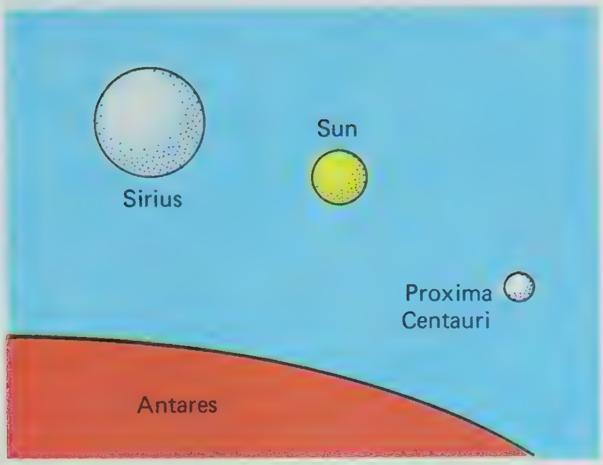


Fig. 61–1

Two well-known stars are ANTARES (an-TA-reez) and Sirius. Compare their size to the sun. The star Antares is so huge, that our sun, plus the earth's orbit could fit into it.

stars are a little bigger than our earth, perhaps 16 100 km in diameter. The largest stars are perhaps 3.22 billion kilometres in diameter, more than 2 000 times as big as our sun! In colorful language we call the small stars *dwarfs;* the big stars are the *supergiants*. You must remember that our sun is a medium-sized star, 1 392 400 km in diameter.

4. COLOR AND BRIGHTNESS

Why are some lamps brighter than others? "Easy," you say, "They are bigger." That is true. But another reason is that as you go closer to a lamp, it seems brighter. Some stars shine brighter than others for the same reason. A bigger star gives off more light than a smaller star. A closer star seems brighter than a distant star of the same size. A hotter star gives off more light than a cooler star.

Stars glow different colors. Stars may be red, yellow, white, blue or green. Our sun, as you know, is a yellow star. The elements in the stars, glowing at different temperatures give off different colors.

The brightness of a star is called its MAGNITUDE (MAG-ni-tood). As far back as 2 000 years ago, stars were set into groups according to their brightness. Since the invention of the telescope, new figures have been gotten. Below are some samples of star magnitudes. The faintest star you can see with the naked eye is in the sixth (6th) magnitude. Polaris, the North Star, is a 2nd magnitude star.

PLANET, STAR AND MOON MAGNITUDES	
Sun	—26.7
Full moon	—12.7
Venus	— 4.4
Jupiter	— 2.5
Mars	— 2.8
Sirius	— 1.43
Antares	+ 1
Polaris (North Star)	+ 2

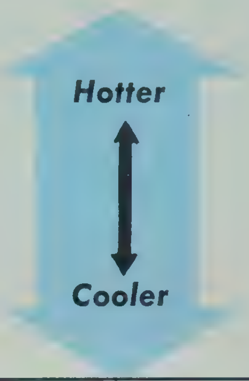
(NOTE: Negative numbers are brighter than positive numbers)

5. HOT STARS AND COOL STARS

You know that stars glow when their elements become incandescent through heat. The heat of stars comes from atomic fusion of hydrogen into helium.

SURFACE TEMPERATURES OF STARS

Star	*Color*	*Temperature*
Rigel	blue-white	12 000°C
Sirius	white	10 500°C
Canopus	yellowish	8 200°C
Sun	yellow	5 530°C
Arcturus	orange	4 200°C
Antares	red	3 127°C



The temperature of stars varies a great deal from one to the other. We can learn the temperature of a star in two ways: first, by its color; second, by the kind of spectrum its light forms through a spectroscope. If we put this data together, we can learn the temperature of the surface of the star. Examine the table above. You will quickly see that the hottest stars are at the blue-white end. The cooler stars are at the red end.

YOU NOW KNOW

- Stars are luminous spheres of hot gases in space.
- Stars vary in size from "dwarfs," which are slightly bigger than our earth, to "supergiants."
- Stars vary in brightness (magnitude) and in color.

6. HOW FAR AWAY ARE THE STARS?

"How far away is your school?" asks your friend. And you answer may be, "Twelve blocks." Or you say, "It's about 15 min from here." Again, we return to the idea of using time to measure distance. A star's distance can be measured by how long it takes its light to reach the earth. You remember that this is called a *light-year.* Proxima Centauri is 40.4 Pm or 4.27 light-years away. It takes that long for its light to reach us. Do you want to know the distance in kilometres? Well, it's 42 trillion kilometres away! But, of course, that figure is one that is almost impossible to imagine.

How do astronomers figure the distance? There are several ways. Astronomers measure the altitude or height of the star above the horizon with a sextant. Another way is to view the star from two different points in the earth's orbit, six months apart. By figuring out the angles formed from each point, you can estimate the distance of the star. This method is called PARALLAX (PAR-a-lax).

Sample Distances of Stars from Earth

Proxima Centauri	40.4 Pm
Sirius	83.2 Pm
Betelgeuse	5 553.0 Pm
Polaris (North Star)	6 167.9 Pm

7. LIFE HISTORY OF A STAR

Stars are being born all the time. But stars do not live forever! Their fuel runs out and they "die." The gases which make up the star condense and contract towards the star's center. As the temperature rises, nuclear fusion begins. Hydrogen begins to turn to helium. The helium forms other, heavier elements. The star now swells.

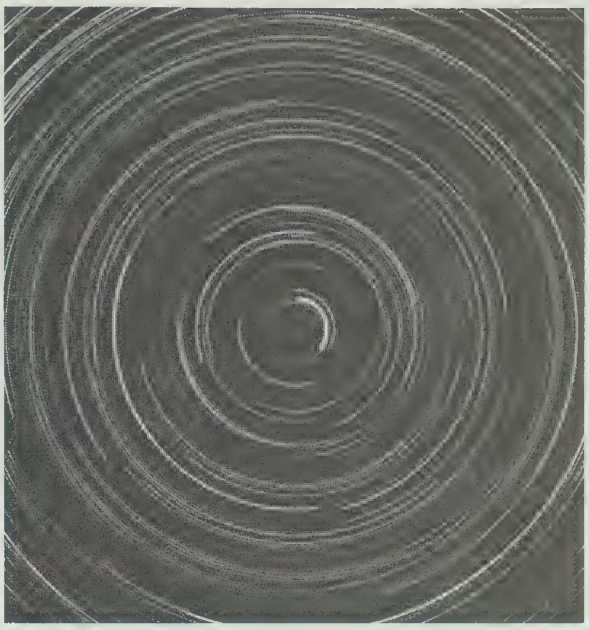


Fig. 63–2

A camera was pointed at the North Star (Polaris) after dark (from about 40° North Latitude). The shutter was open for about 8 h. Can you explain what happened? Is Polaris the only star shown? Explain.

SKIES OF THE NORTHERN HEMISPHERE

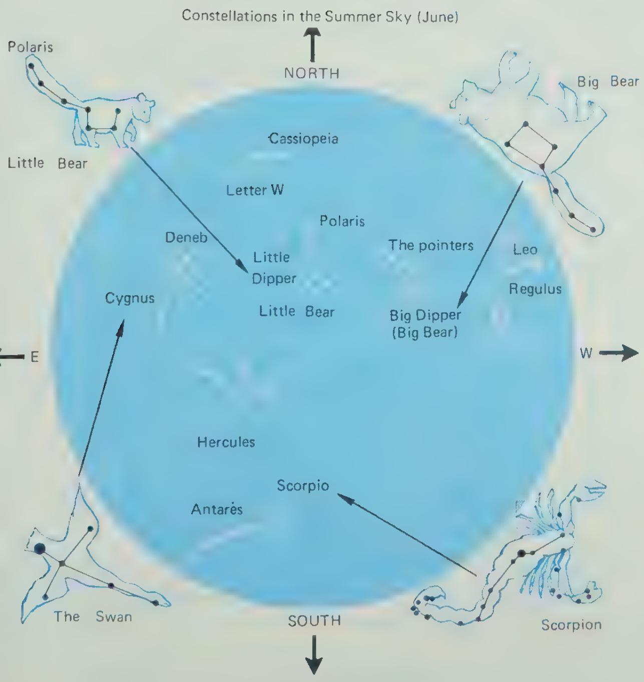


Fig. 63–1A

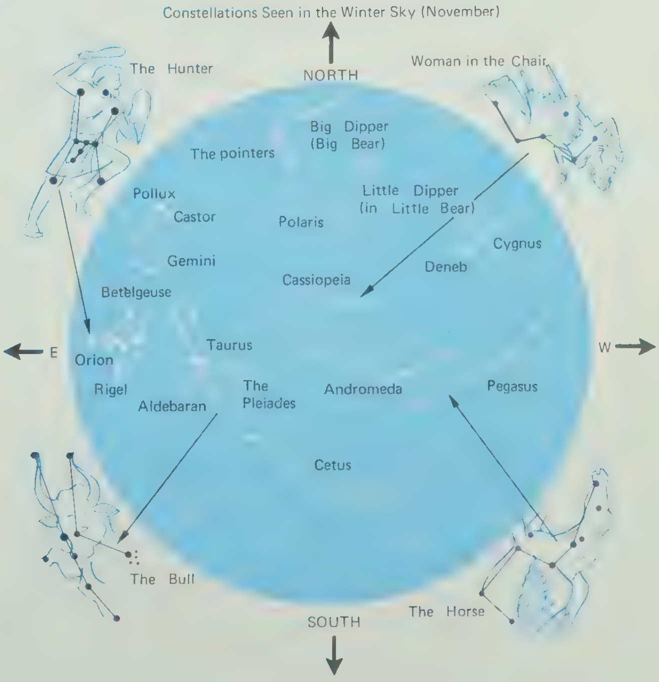


Fig. 63–1B

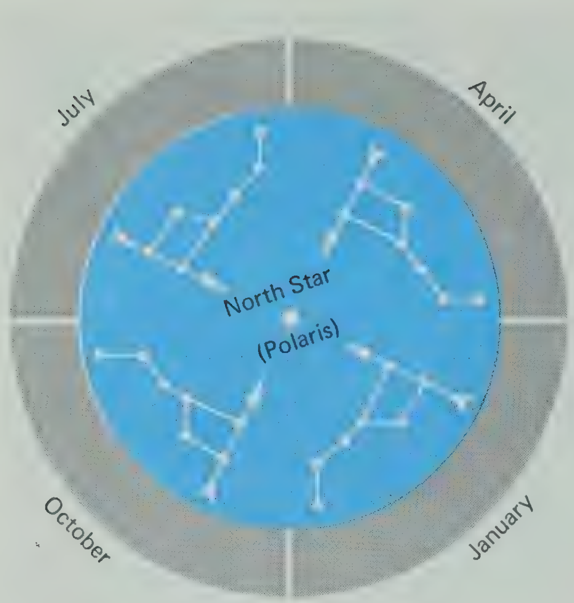


Fig. 64–1

In the Northern Hemisphere, the Big Dipper (part of the Big Bear) can be seen at all seasons of the year around Polaris. The two "pointer stars" always point to Polaris.

Then the temperature grows less and less. The star turns "dead." The stars we see are in many age groups, from youngest to oldest.

Sometimes dim stars which cannot be seen at all suddenly flare up. When Tycho Brahe first saw such a star in 1572, he called it a *nova* which meant "new." He was, however, mistaken. It was not a new star at all. It was a star in the last stage of its life. Shortly before stars "die," they blaze brightly.

8. BIRDS AND BEARS . . . DOGS AND DIPPERS

Animals in the skies? Of course, not! But in ancient days, when people looked at the skies, they saw groups of stars that seemed to form familiar shapes. We call such groups *constellations*. In ancient days, astronomers listed 48 constellations. Today, with good telescopes, about 90 groups have been charted.

Since the earth revolves in its orbit beneath the skies, we do not see the same constellations all the time. At different seasons, we see different constellations. Astronomers have been able to draw sky maps to show these. Your teacher can demonstrate the familiar sky maps. With a little practice, you can get to know the most common constellations.

UNDERSTANDING WHAT YOU HAVE READ

I. What are the two main ideas in Chapter 9?

1. The ancient people knew all about grouped stars.
2. Stars are distant suns whose characteristics are well known.
3. Stars are born, develop, glow and disappear.
4. We cannot see stars during the day, but they are there all the time.

II. In which paragraph do you find the the answer?

1. How does the temperature of a star affect its color?
2. How does the sun compare to other stars?
3. What is parallax?
4. In which constellation do we find Polaris?

III. Knowing What and Why

1. The sun is large and bright because
   - a. it is the largest star of all.
   - b. it is the closest to earth of all the stars.
   - c. it has the most hydrogen.
   - d. it has the highest temperature of all stars.
2. The sun is a
   - a. red giant.
   - b. white dwarf.
   - c. red dwarf.
   - d. yellow star.
3. The magnitude of a star depends on
   - a. its temperature.
   - b. its size.
   - c. its distance.
   - d. all of the above.
4. The stars we see in summer are different from those in winter because
   - a. the stars move south.
   - b. the sun forms an eclipse.
   - c. summer stars are old stars and "die" by the winter.
   - d. the revolution of the earth gives us a new view.

IV. Match the words in *Column A* with the words in *Column B*

A	*B*
1. The Hunter	a. white-hot
2. incandescent	b. constellation
3. Polaris	c. Milky Way
4. hydrogen fusion	d. bright star
5. Sirius	e. red star
6. sudden flare-up of star	f. helium
7. Big Dipper	g. North Star
8. Antares	h. nova
	i. galaxy
	j. pointer stars

V. For the Amateur Scientist

Obtain strips or wires of different metals: iron, copper, steel. Put on a pair of gloves. Hold each piece of metal with pliers over a gas flame. Observe the colors as the metal grows hotter. How does this explain the color of stars?

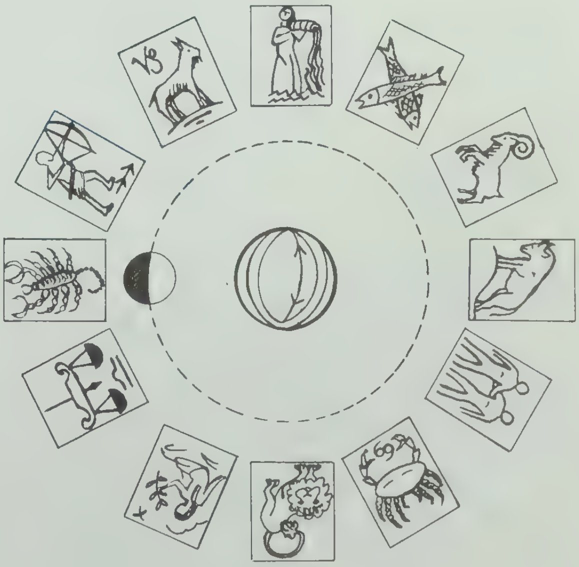
VI. Brain Teaser

How can a person count the stars in the skies?

Hint: How can you get a good estimate of the number of words on a page in a book *without counting each word?*

VII. For the Artists and Craftsmen

1. Make constellation charts. Get some shirt cardboards. In pencil, draw on a constellation on each board. (See Fig. 63–1A and Fig. 63–1B.) Where a star should appear, punch a hole with a pencil. Hold the board up to a lamp in a darkened room. You will see lighted constellations.
2. Draw the 12 constellations shown on the diagram below. Use a file card for each one. The basketball represents the sun. The baseball is the earth. Use this setup to show why we see different constellations at different seasons.



Glossary: What Does It Mean?

Amateur	AM-a-chur	A person who does something for enjoyment rather than for money.
Antares	an-TA-reez	A very large star.
Apollo	a-POL-o	The Greek god of the sun. Also, the name given to certain American spaceships.
asteroids	AS-tur-oyds	Tiny planets that revolve around the sun in orbits, mostly between Mars and Jupiter. Also called planetoids.
astronomer	uh-STRON-uh-mer	A scientist who studies the size, shape, position and makeup of the objects in the universe.
chromosphere	KRO-mo-sfeer	The glowing layer of gas that surrounds the sun's photosphere. It can only be seen during a solar eclipse.
chronograph	KRO-no-graf	An instrument used for measuring and recording precise time.
comet	KOM-it	A body in our solar system with a gaseous tail which always points away from the sun. It orbits the sun.
concave		Circularly shaped or curved inward as the inside of a soup bowl.
constellation	kon-stuh-LAY-shun	A group of stars that man has named after animals or mythical characters.
convection zone		The area of hot gases that surrounds the core of the sun.
convex		Circularly shaped or curved outward as outside of a tennis ball.

corona	kuh-RO-nuh	The outer layer of the sun's atmosphere. It is seen as a silvery halo during a solar eclipse.
Dark Ages		The time between 400 A.D. and 1000 A.D. when little or no learning took place in Europe.
electromagnetic spectrum		A chart or diagram showing the arrangement of radiant energy rays according to wavelength.
ellipse	ee-LIPS	An oval or flattened circle with two foci.
galaxy	GAL-ax-ee	A system of stars with dust and gases. Our galaxy is the Milky Way.
Great Red Spot		An area on Jupiter that grows darker red every 30 years.
helium	HEE-lee-um	A very light, gaseous element first discovered in the sun.
incandescence	in-kan-DES-ens	The glow which occurs when a material is heated to a high temperature.
Jupiter	JU-pit-er	The largest of the planets and fifth from the sun.
Kohoutek	ko-HOO-tek	A comet that came into the earth's view in 1973.
magnitude	MAG-ni-tood	A measure of a star's brightness.
Mars	MARZ	The planet which appears red and is fourth from the sun.
Mercury	MUR-kur-ee	The fastest of the planets. It is the closest of the planets to the sun.
meteor	MEE-tee-or	A mass of metal or stone that is heated by friction as it enters the earth's atmosphere. Also incorrectly called a shooting star.
meteorite	MEE-tee-uh-rite	A meteor that is not entirely burned up before it hits the earth.
meteorologist	MEE-tee-or-ol-o-jist	A scientist who studies the atmosphere as it affects the weather.
Milky Way		The huge star system (galaxy) of which the earth is a member.
navigation	nav-i-GAY-shun	The method of directing a ship, airplane or spaceship from one place to another.

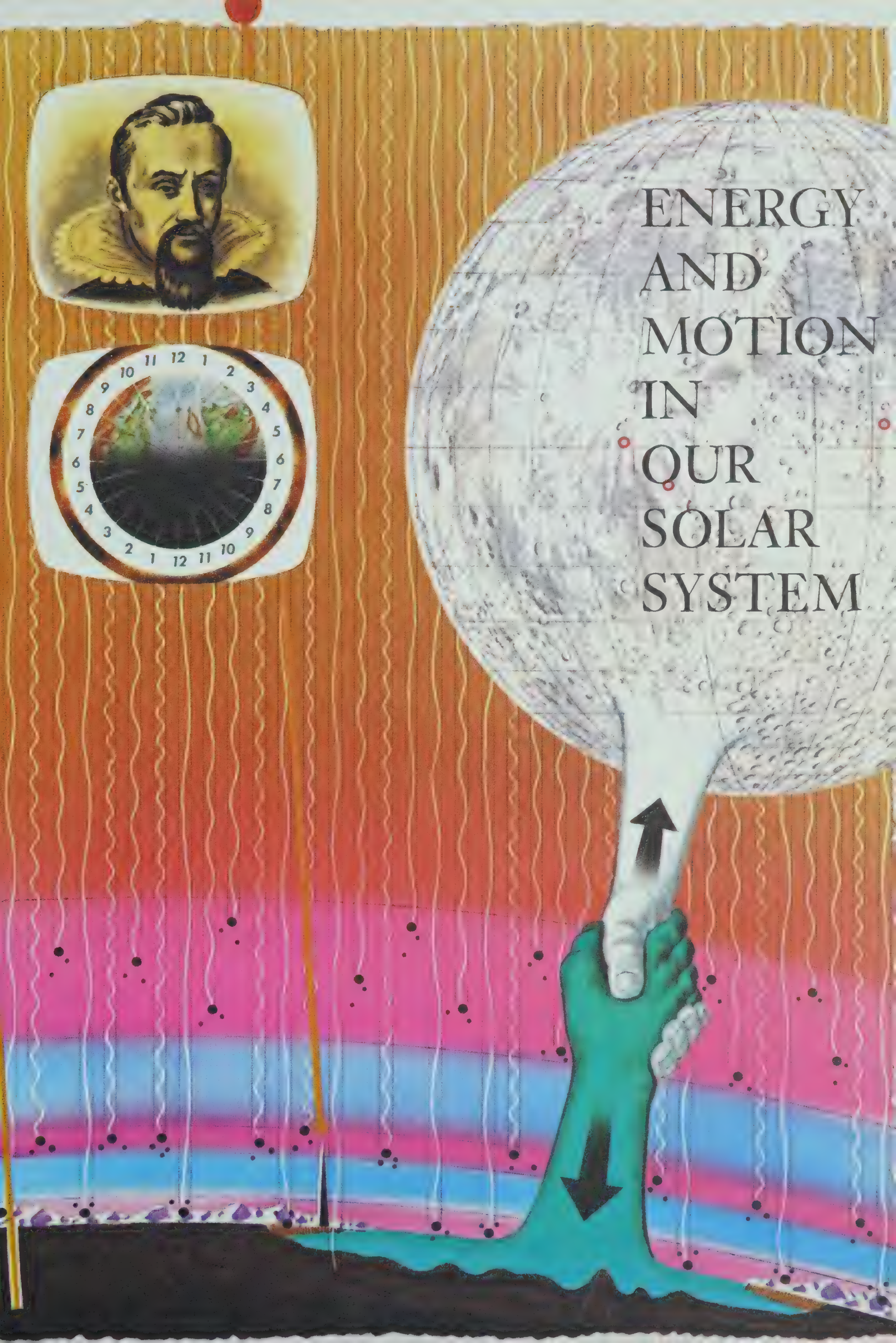
nova	NO-vah	The sudden brightness of a dim star. It will eventually become dim again.
objective lens		The large lens in a telescope that is closest to the object being viewed.
observatory	ob-ZUR-vuh-to-ree	A building containing telescopes and other instruments used to study the skies.
optical window		The range in the spectrum of light that is not absorbed by the atmosphere.
orbit	OR-bit	The path of a planet or body as it revolves around another body. An example is the earth's orbit around the sun.
ozone	OH-zohn	A gas which is found in a thick layer about 32 km above the earth. It absorbs ultra-violet radiation.
parallax	PAR-a-lax	The apparent change in the position of a heavenly body when observed from two different points.
petroleum	puh-TRO-lee-um	An oily liquid which occurs naturally. It is used in the making of gasoline.
photometer	fo-TOM-i-tur	An instrument which measures the brightness of a light source, such as a star.
photosphere	FO-to-sfeer	The layer of gas that surrounds the sun that can be seen.
photosynthesis	FO-to-SIN-the-sis	The process that in the presence of sunlight, produces food for green plants.
planetarium	plan-uh-TAIR-ee-um	A projection instrument used to demonstrate the positions and motions of the heavenly bodies. Also, the dome-shaped building which houses the projector.
planetoids	PLAN-i-toyds	Small planets that revolve around the sun in orbits, usually between Mars and Jupiter. Also called asteroids.

planets	PLAN-its	The nine large bodies which revolve in orbits around the sun in our solar system.
radio window		The area of the spectrum that allows radio waves to come through.
radiosonde	RAY-dee-o-zond	An instrument, used in weather forecasting, which is carried up in a balloon in the upper atmosphere. It transmits weather conditions such as humidity and temperature to the earth by radio waves.
revolution	rev-o-LOO-shun	The motion of a planet in its orbit around the sun.
rotation	ro-TAY-shun	The spinning action of a heavenly body on its axis.
Saturn	SAT-urn	The sixth planet from the sun.
space probe		A fired satellite which either remains in space orbit, or returns to earth.
spectroscope		An instrument for studying light.
spectrum	SPEK-trum	The band of colors, like a rainbow, formed when light passes through a glass prism.
sunspots		Dark markings on the surface of the sun. They seem to disturb the radio signals on earth.
surveyor	sur-VAY-ur	A person who measures points on the earth in relation to other points.
thermocouple	THER-mo-kup-ul	An instrument used to measure surface temperatures of heavenly bodies.
thermonuclear reaction	THERMO-NEW-klee-ur	The joining of atoms to produce a larger atom plus energy. Also called nuclear fusion.
transit	TRAN-zit	An instrument used to measure angles.
Venus	VEE-nus	The second planet from the sun.

UNIT III

Eratosthenes (top left), a Greek astronomer, was the first person to figure out the circumference of the earth. His method is shown by the position of the two suns (top and left). The globe under Eratosthenes' picture shows twenty-four hours of the day at all points of the equatorial circumference. The friendly gesture of shaking hands (right) shows the pull of the moon that gives the earth its tides and gravity. The bands (orange, pink, blue) show how the atmosphere stops deadly rays from reaching the earth.

ENERGY AND MOTION IN OUR SOLAR SYSTEM



UNIT III

Energy and Motion in Our Solar System

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10

TARGET
What is the shape and size of the earth?

The Shape and Size of the Earth

1. WHAT IS THE EARTH'S SHAPE?

A common mistaken idea is that Columbus was the first to show that the earth was not flat. It may have been true that at Columbus's time, large numbers of uneducated people believed the world was flat. But certainly people with knowledge knew differently. We spoke earlier of the Greek scientist, Eratosthenes, who figured out the circumference of the earth way back in 250 B.C. A circumference is a distance around a sphere. Therefore, many people, even then knew that the earth was not flat. What was their evidence?

2. EVIDENCE FROM WATCHING SHIPS

The Ancients, watching ships sail away, looked at the HORIZON (huh-RY-zun). The horizon is where the sky seems to touch the earth. As the ships moved farther away from the observer, the bottom of the ship disappeared from sight first; then the middle was not seen. The last part to disappear was the top of the boat (sail masts). If the earth were flat, the whole boat would seem to disappear from your view at the same time, not the bottom first.

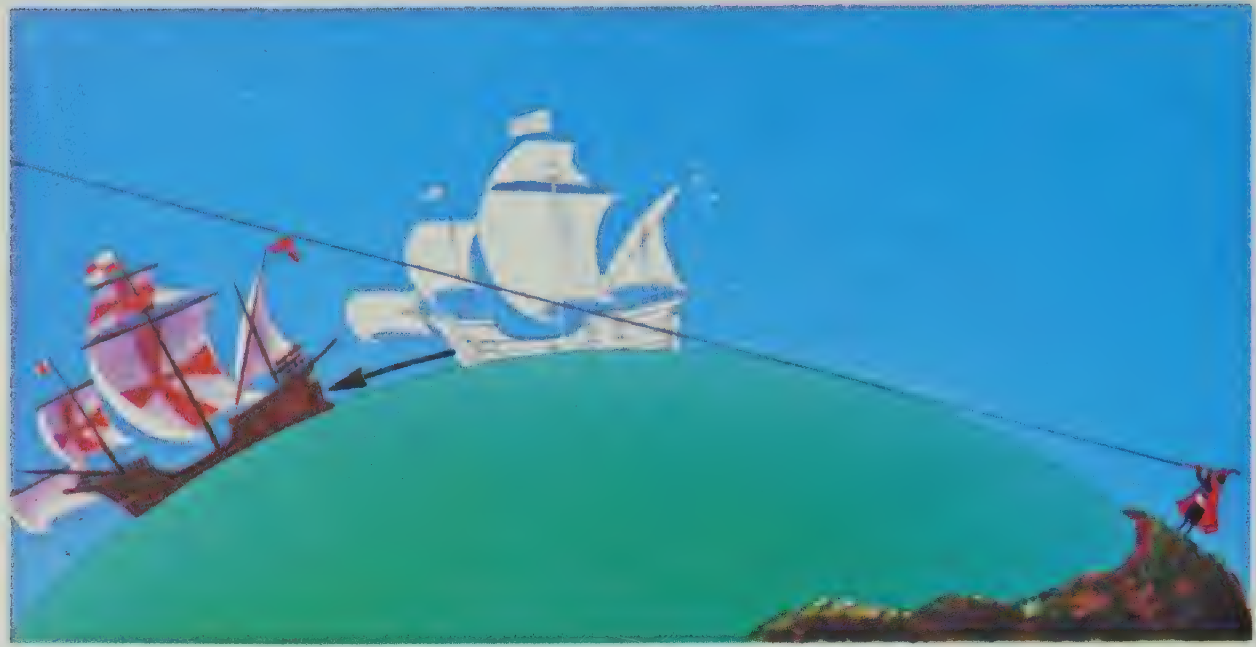


Fig. 76–1

Which part of the ship will be seen last when the ship sails out of the harbor?

3. EVIDENCE FROM THE ALTITUDE OF STARS

The sailor in Fig. 76–2 is using a *sextant* to measure the height (altitude) of a star above the horizon. If another sailor, 1 000 km away, measured the altitude of the same star, he would find that it is "higher" in the sky. The chart in Fig. 77–1 shows that on a flat earth, the star would appear the same height. On a curved earth, it is higher. This is why the North Star, Polaris, seems to be high in the sky in northern parts of the earth and lower in the sky as you move south. At the equator, the North Star is at the horizon.

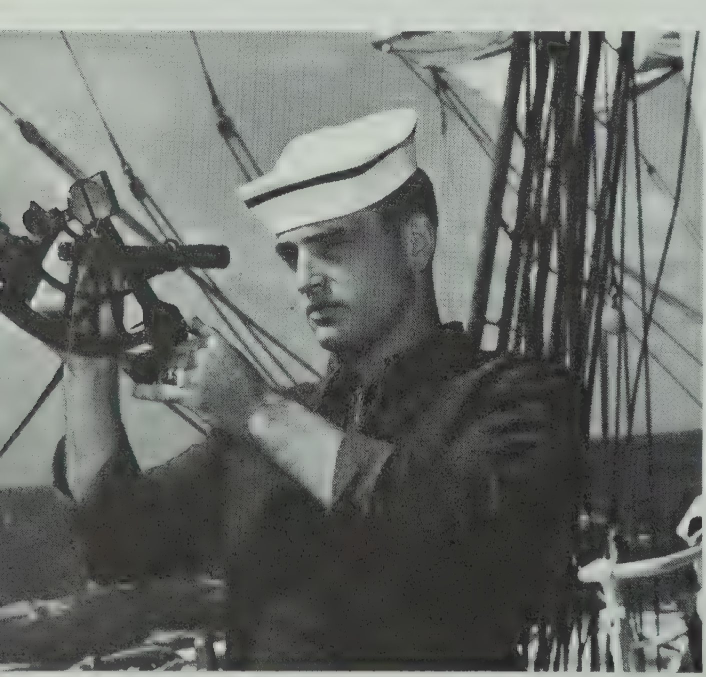


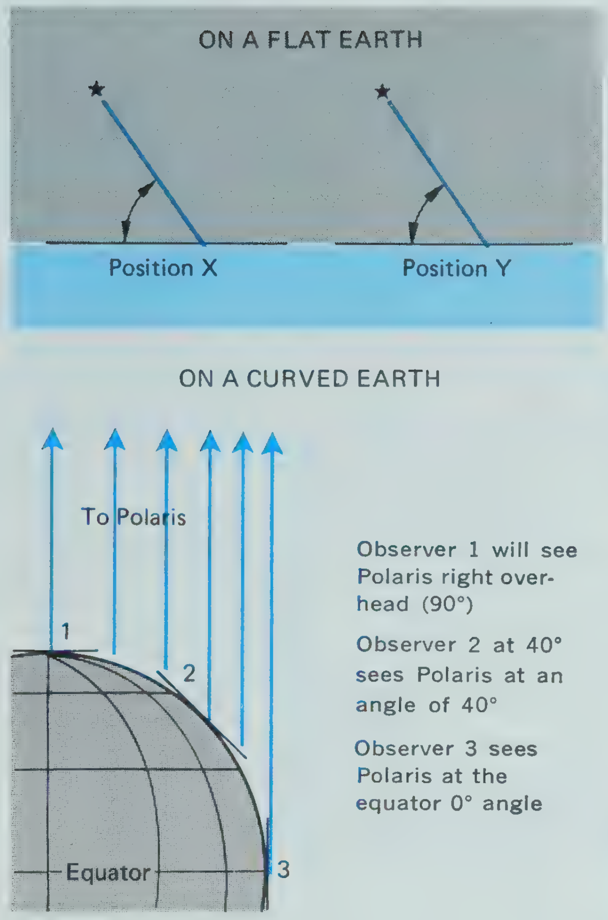
Fig. 76–2

This sailor can use a sextant to measure the height of stars by angles.

4. WE CAN SEE IT, TOO

An ECLIPSE (ee-KLIPS) is the darkening of a body in space by the shadow of another body. An eclipse of the moon shows a circular shadow of the earth on the moon. We shall study eclipses in a later chapter.

Now, in the age of space flights, we have been able to get far enough away



Observer 1 will see Polaris right overhead (90°)

Observer 2 at 40° sees Polaris at an angle of 40°

Observer 3 sees Polaris at the equator 0° angle

Fig. 77–1

The same star appears at different heights because the earth is curved.

in space to see the entire earth. For example, in Dec. 1972 the space capsule *Apollo 17* took color photographs of the earth and sent them through space to our TV sets. Millions of people saw the earth as if they were in space. It appeared as a blurry ball of white light on a blue background. It was a not-too-perfect sphere. (See Fig. 79–1.)

Evidence that the Earth Is a Sphere	Sailing ships' masts Altitude of stars Eclipses of the moon View from satellites

5. THE EARTH'S STATISTICS

Have you wondered how we can ever measure the earth? Of course, you can see that a ship sailing the ocean or a plane circling the globe, can figure the total number of kilometres it has travelled. That is easy. But how did the ancient people know this answer? Let us see.

Look at Fig. 78–1. The sun is directly overhead. There is no shadow. When a shadow is formed by the sun, its rays must be slanting. This simple idea was used by Eratosthenes in 250 B.C. to figure the *circumference* or distance around the earth.

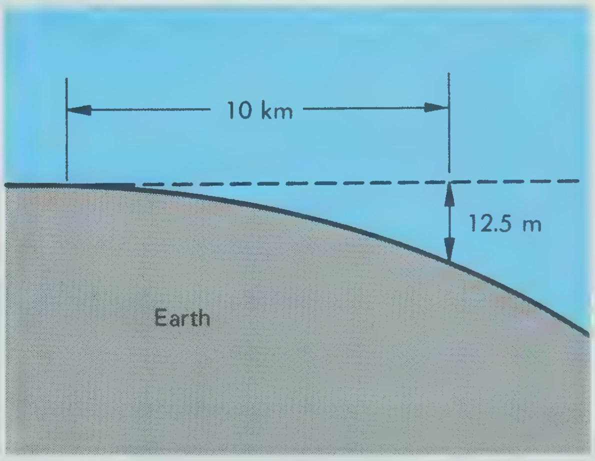


Fig. 77–2

The curve of the earth is very gentle. In 10 km, the curve drops only 12.5 m.

ERATOSTHENES' PROOF OF THE EARTH'S SIZE

In the city of Syene (now Aswan), Egypt, Eratosthenes found a deep well. On June 21, the sun shone directly overhead to the bottom of the well. There were no shadows.

At that very moment, in Alexandria, Egypt, a friend measured the angle of a shadow made by a vertical pole. The angle formed was 7.2°. Eratosthenes knew then what you also know: a full circle has 360°. Simple arithmetic showed that 360° is 50 times 7.2° (7.2 × 50 = 360).

Alexandria was 804 km north of Syene. This 804 km is only part of the sphere of the earth. What part? Well, if 50 × 7.2° = 360°, then 50 × 804 km should give the size of the whole sphere: 50 × 804 km = 40 200 km. The circumference of the sphere of the earth is 40 200 km.

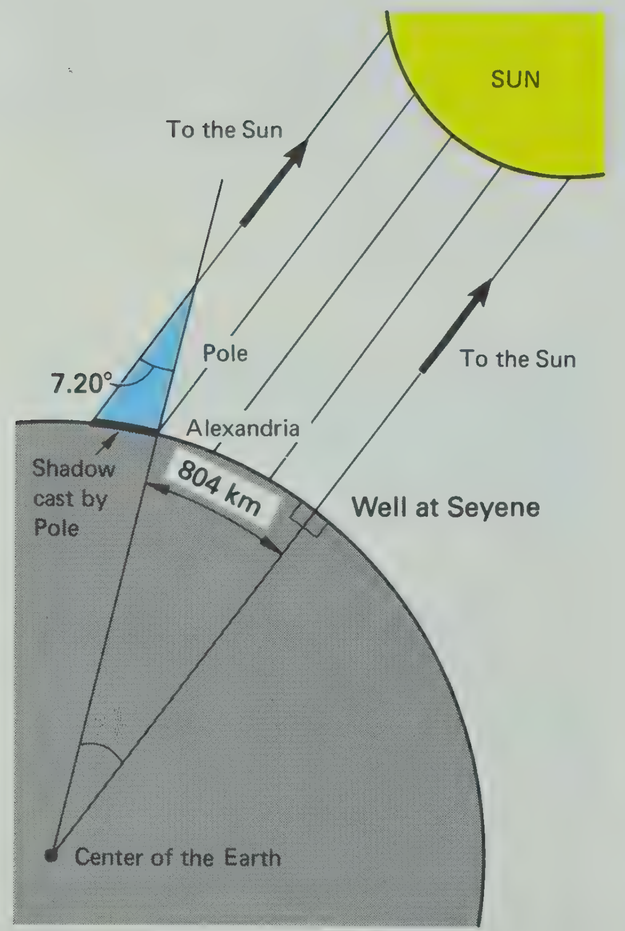


Fig. 78–1

Careful observation and simple arithmetic gave Eratosthenes the circumference of the earth.

Now, if we know the circumference, the rest is easy. In your study of mathematics, you have learned a formula for the diameter of a circle or sphere.

Diameter = Circumference ÷ π

$$\pi = \text{Pi} = \frac{22}{7}$$

$$D = 40\,200 \div \frac{22}{7} \quad \text{so } D = \frac{\frac{40\,200}{1}}{\frac{22}{7}}$$

$$D = \frac{40\,200 \times 7}{22} = \frac{281\,400}{22} = 12\,791 \text{ km}$$

The diameter of the earth is approximately 12 800 km.

6. IS THE EARTH A PERFECT SPHERE?

A tennis ball and a Ping-Pong ball are *perfect* spheres. The diameter, through the center, is the same all over the sphere. But we know that the earth is not a perfect sphere. It is flattened a little at the poles. It bulges (is fatter) at the equator. Fig. 78–2 shows the two different diameters.

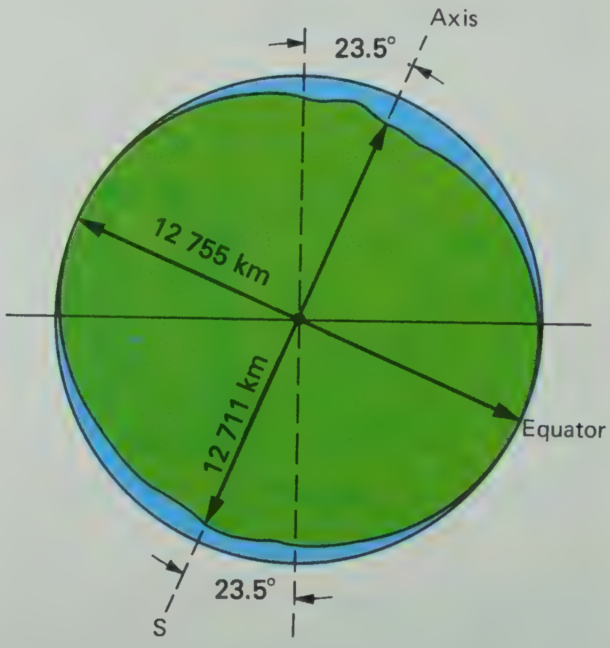


Fig. 78–2

The two diameters are a little different. The earth's sphere (in green) is shown on top of a perfect sphere (blue).

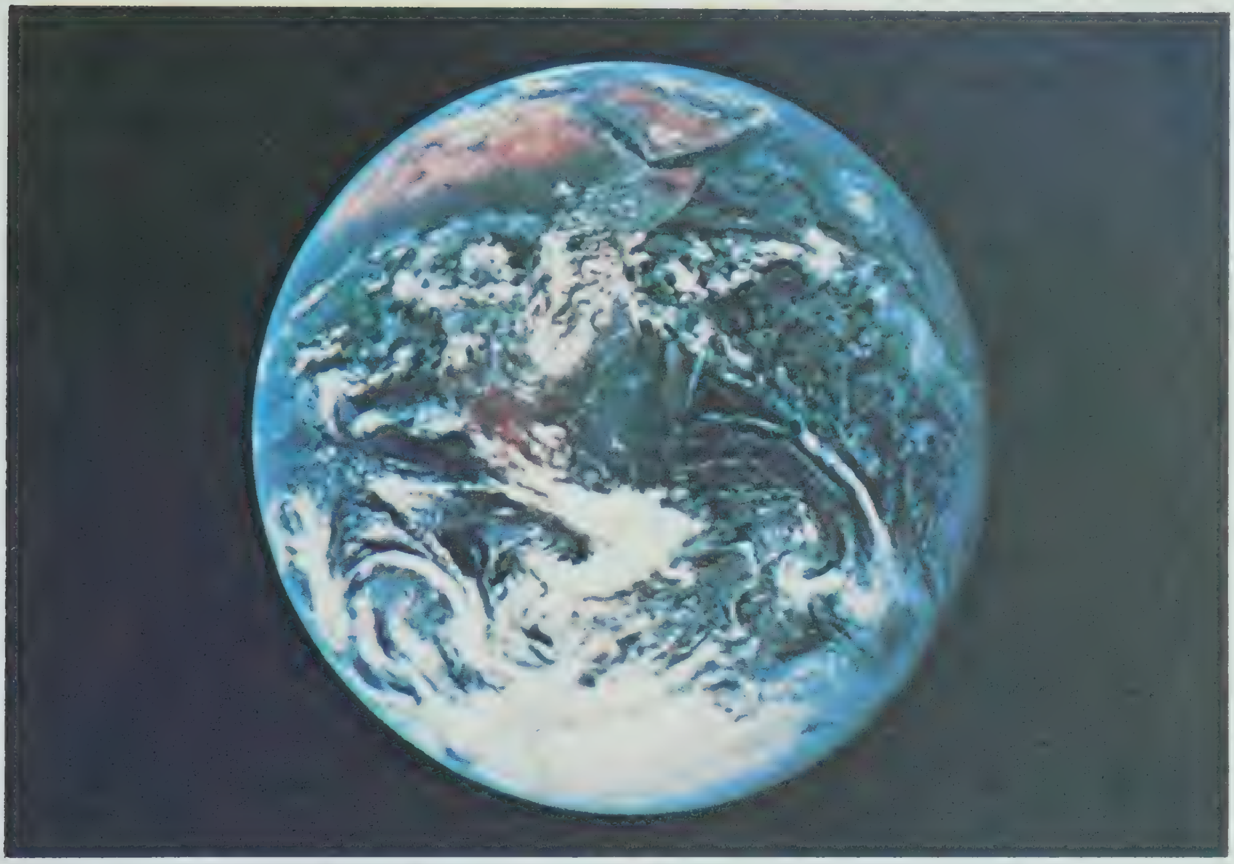


Fig. 79–1

The shape of the earth as seen from Apollo 17. The area shown extends from the Mediterranean area to the Antarctic polar cap.

YOU NOW KNOW

- The earth is an irregular sphere, flattened at the poles, bulging at the equator.
- Eratosthenes proved by angles and shadows that the earth's circumference is 40 200 km. By mathematics, we find the diameter to be about 12 800 km through the center.

UNDERSTANDING WHAT YOU HAVE READ

I. What are the two main ideas in Chapter 10?

1. The earth is a sphere with irregular dimensions.
2. Columbus's work on navigation was not too important.
3. The earth's curve is very gentle.
4. The earth is one of the smaller planets which orbit the sun.

II. In which paragraph do you find the answer?

1. How is a sextant used to prove that the earth is not flat?
2. How long ago was the size of the earth figured out?
3. How can we figure the diameter of the earth?
4. Which diameter of the earth is the shortest?

III. Knowing What and Why

1. On a *flat* earth, a star viewed from Southern Italy and from Northern England would show
   a. both stars at the same height.
   b. the star in Italy at a lower position.
   c. the star in Italy at a higher position.
   d. that no two stars are alike.
2. When Eratosthenes figured the circumference of the earth, he used
   a. the stars in Alexandria.
   b. angles and shadows.
   c. a full moon.
   d. the planet Venus.
3. As a boat leaves the harbor,
   a. the whole boat disappears at the same time.
   b. the top of the boat is the last part to be seen.
   c. the bottom of the boat is the last part to be seen.
   d. it slows its speed.
4. In the diagram of Eratosthenes' work (Fig. 78–1),
   a. the rays of the sun are unimportant.
   b. the sun's rays are directly overhead in Syene.
   c. there is a heavy shadow in the well.
   d. the distance of 804 km has to be doubled.

IV. Choose the word from inside the parentheses to correctly complete each sentence.

1. The diameter of the earth at the equator is 12 711 km, 12 800 km.
2. The figure Pi (π) stands for (22/7, 7/22).
3. A sextant measures (shadows, angles).
4. The sky "meeting" the water of the ocean forms (its altitude, the horizon).
5. Eclipses are (shadows, satellites).

V. Try These Problems

1. The moon's diameter is 3480 km. What is its circumference? Show your work.
2. The diameter of Mars is 6759 km. What is its circumference? Show your work.

   Hint: Circumference $= \pi \times D$

VI. For the Science Reporter

At the library, borrow the *Picture Book of Astronomy* by Roy Gallant. Read about the ancient observatory in Alexandria. Write a report for your class.

VII. For the Artist

Using a large poster board, make a copy of Fig. 78–2, the shape of the earth. Use colors. Bring it to class.

11

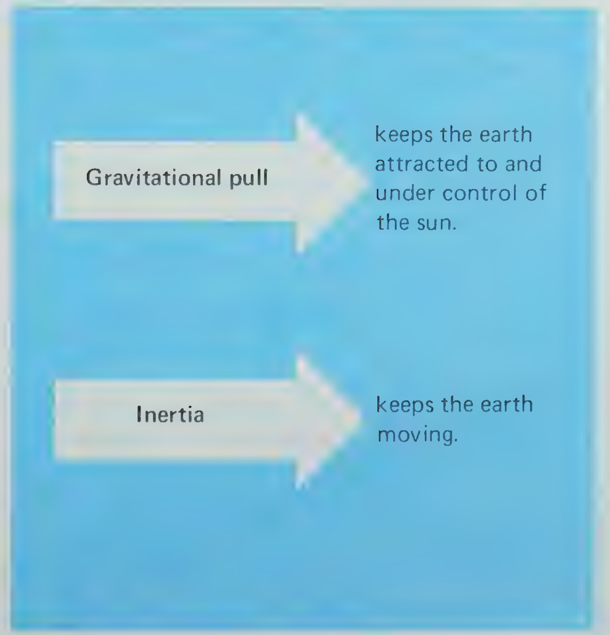
TARGET
How can we prove the earth's motions?

The Earth in Motion

1. LOOKING BACK . . .

Galaxies, or systems of stars, spin in space. The Milky Way, our galaxy, contains a group of bodies called the Solar System. Our sun is the star at the center of this solar system. Nine planets revolve around the sun in regular orbits. The third planet from the sun is our earth.

Like all other astronomical bodies, the earth is controlled by known forces.



2. OUR SPINNING EARTH

Night and day, seasons, eclipses, star positions and planets all point to one conclusion. Copernicus and other astronomers knew that the earth must be moving. Of course, this sounded reasonable. However, as you have seen, before a scientist accepts an explanation, it must be not only reasonable, but it must be *proved*.

3. EVIDENCE OF THE EARTH'S ROTATION

Spin a globe and watch it. It is spinning about a metal rod called an *axis*. The axis goes right through its center. Now imagine the globe to be the earth. Of course, there is no real axis going through the earth. Rotation is movement around the imaginary axis. In other words, the whole sphere spins. Turn yourself round and round while you stand in one spot. You are rotating.

In about 1851, a French scientist, JEAN FOUCAULT (JON foo-KOH)

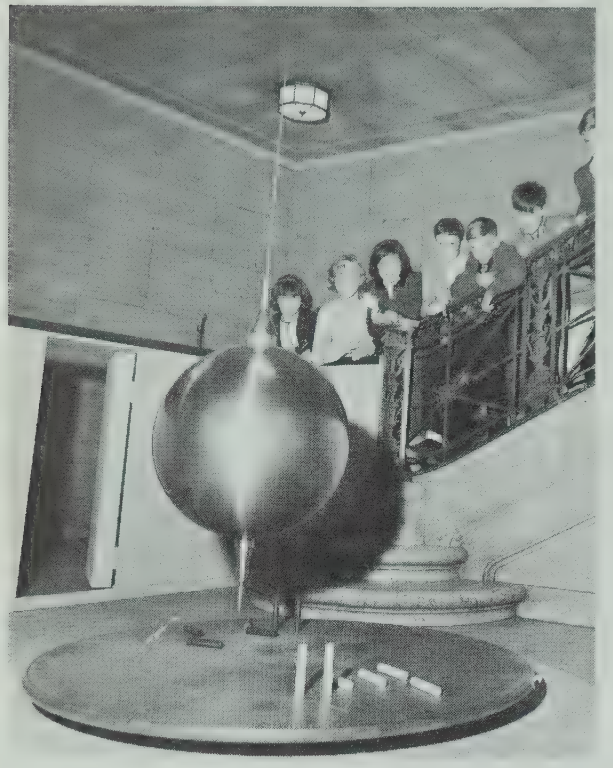


Fig. 82–1

These pupils are watching as the Foucault pendulum swings back and forth. Why are some of the pegs knocked down?

performed an amazing demonstration. The photograph in Fig. 82–1 shows a similar demonstration in the Franklin Institute in Philadelphia. Foucault hung a heavy cannon ball at the end of a thin, strong 67-m wire. Then he hung the ball and wire from a swivel joint on a beam in the famous Pantheon building in Paris, France. The ball hung above a layer of sand on the floor. He attached a pointer to the ball and began to swing the ball back and forth in the form of a pendulum. The results were astounding.

When a pendulum swings freely, it moves back and forth along the same line. If so, you would think that Foucault's pendulum would scratch a line in the sand back and forth in the same direction. But, no! As the pendulum swung, it seemed to change its line. The line that was scratched moved through an almost perfect circle of 360°. This showed that the earth was spinning under the pendulum. Foucault had proved that our earth spins, or rotates. (*Note:* These precise results can be gotten only at the North Pole. In New York or Paris, you have to make mathematical corrections.)

4. OUR OWN EXPERIMENTS ON ROTATION

Would you like to see how the earth's rotation works? There are some experiments that can be done easily.

DO AND DISCOVER

Investigation 2: How can we show the earth's rotation?

What you do:

Fasten a screw eye into a stick (S). Hang a heavy plumb bob from a brass wire. Attach the wire to a special screw eye on a swivel joint. Lay the stick over the edges of a pail. Now stand the pail on a piano stool that can turn. Start the pendulum swinging. Now rotate the stool slowly.

What you see:

You will see that the pendulum continues to swing in the same back and forth directions no matter what the position of the stool.

What you learn:

If you could look down at the North Pole from a satellite, you would see the earth spinning under the pendulum (Fig. 83–1B). The pendulum would be hanging from the satellite which is standing still.

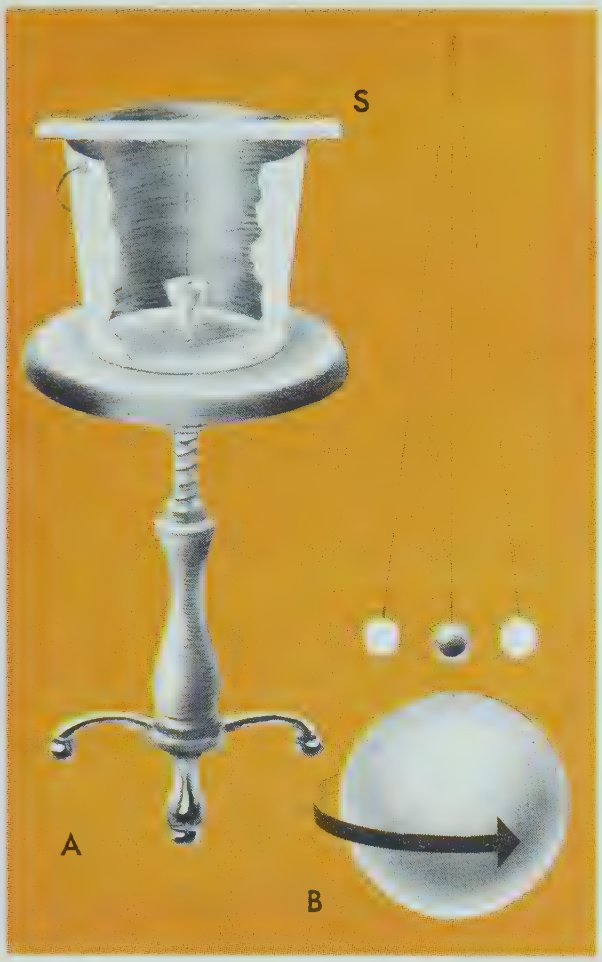


Fig. 83–1

DO AND DISCOVER

Investigation 3: How can we show the earth's rotation another way?

What do you do:

The best place to do this experiment is in the gymnasium which has a high ceiling. Attach an 8-kg shot (from your Health Education Department) to a brass wire which is at least 4 m long. The top end of the wire should be attached to a strong hook in a ceiling. Pull the mass to one side and tie it to a table with a piece of cord. Draw a chalk line across the floor in the exact path that the pendulum will swing. Place a plastic bottle on the floor slightly to the right of the pendulum. Now, at arm's length, burn the holding cord with a match to start the pendulum.

What you see:

After about 10 min, the pendulum will no longer be over the chalk line. In about 30 min, the pendulum ball will knock over the plastic bottle.

What you learn:

The pendulum followed its own path. The earth is moving under it. *Note:* The longer the wire, the more precise the results.

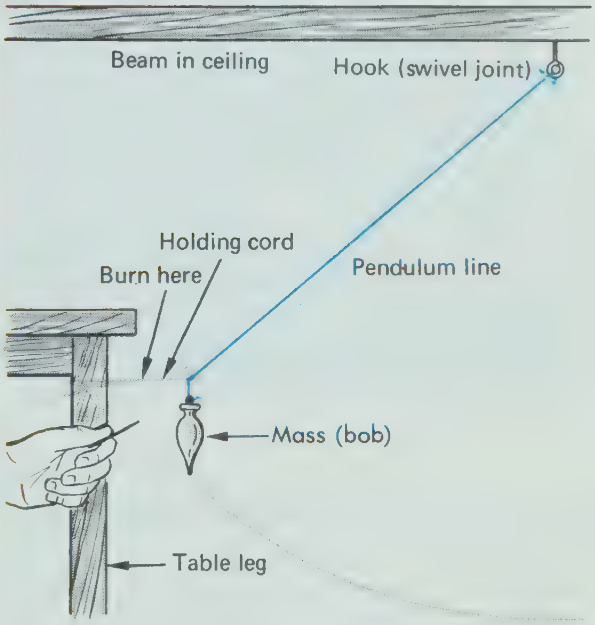


Fig. 83–2

5. WHICH WAY? HOW FAST?

Look back at Fig. 78–2. The diameter passing through the earth from North Pole to South Pole is the imaginary axis about which the earth rotates. It rotates from *west* to *east*. The diagram also shows you that the earth's axis leans (tilts) over from the vertical to form an angle of about 23.5°. (See Fig. 84–1B.)

How fast does the earth spin? It has to spin (rotate) 360° to spin 40 200 km.

Simple arithmetic shows you that it spins about 1700 km/h at the equator. As you move towards the poles, the circumference gets smaller. The distance therefore becomes a little less. Fig. 84–1 compares the distances of rotation at various parts of the earth.

YOU NOW KNOW

- The earth rotates around an imaginary axis counterclockwise, from west to east.
- The earth spins at 1700 km/h at the equator. It spins more slowly, north and south of the equator.
- A free-swinging pendulum was first used by Foucault to prove rotation of the earth.

6. THE EARTH'S ORBIT AROUND THE SUN

Stand a lamp, without a shade, in the middle of a table. The lamp represents the sun. Now take the globe which you used before. Spin it, and at the same time, move it completely around the "sun." You are demonstrating that the *rotating* earth is also *revolving* around the sun.

The earth, like the other planets, moves around the sun in an orbit. Until the time of Johannes Kepler (1571–1630), the orbits were thought to be perfect circles. He showed that the earth and the other planets move around the sun in orbits which are slightly oval or elliptical. It is very important to understand an ellipse and how it is different from a circle. Let us find out.

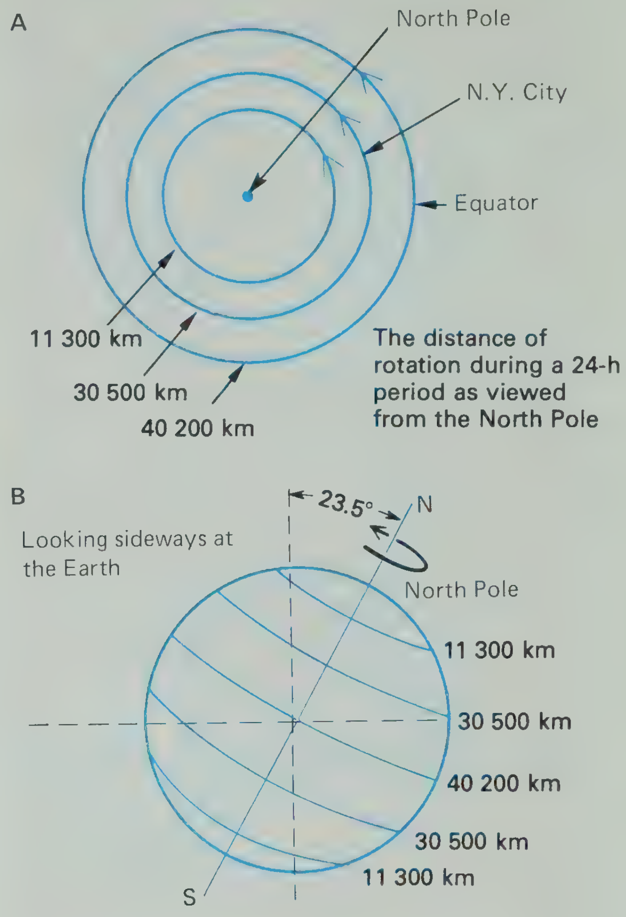


Fig. 84–1

The earth spins counterclockwise. Where is the circumference the largest?

DO AND DISCOVER

Investigation 4: How can we draw an ellipse?

What you do:

1. Get a piece of string 36 cm long. Tie it into a loop (Fig. 85–1A).
2. Get a sheet of corrugated cardboard, about 45 cm × 50 cm.
3. Place the two pins in the cardboard about 15 cm apart; slip the loop over the pins.

4. Place the pencil inside the loop. Pull gently to the edges. Run the pencil all around to draw the figure (Fig. 85–1B).
5. Move the pins to be 5 cm apart; repeat the drawing.
6. Put both pins together. Draw the figure.

What you see:

In Step 4, you have drawn an ellipse. In Step 5, the ellipse is wider. In Step 6, you have drawn a circle.

What you learn:

An ellipse is a figure that is drawn around two points (each point is a *focus;* plural, *foci*). As the foci move farther apart, the ellipse gets longer and narrower. As the foci are moved closer together, the ellipse becomes more and more round. It finally becomes a circle.

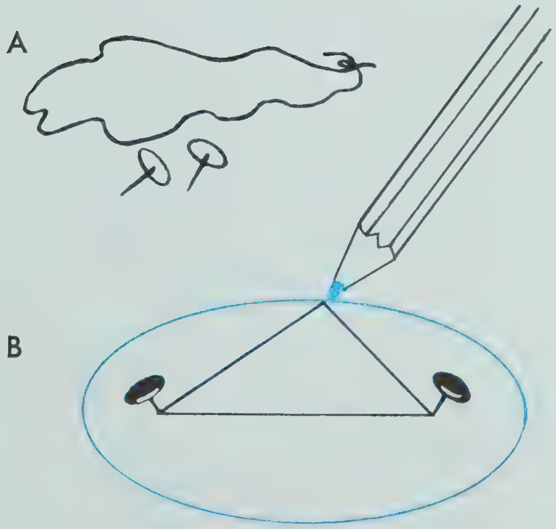


Fig. 85–1

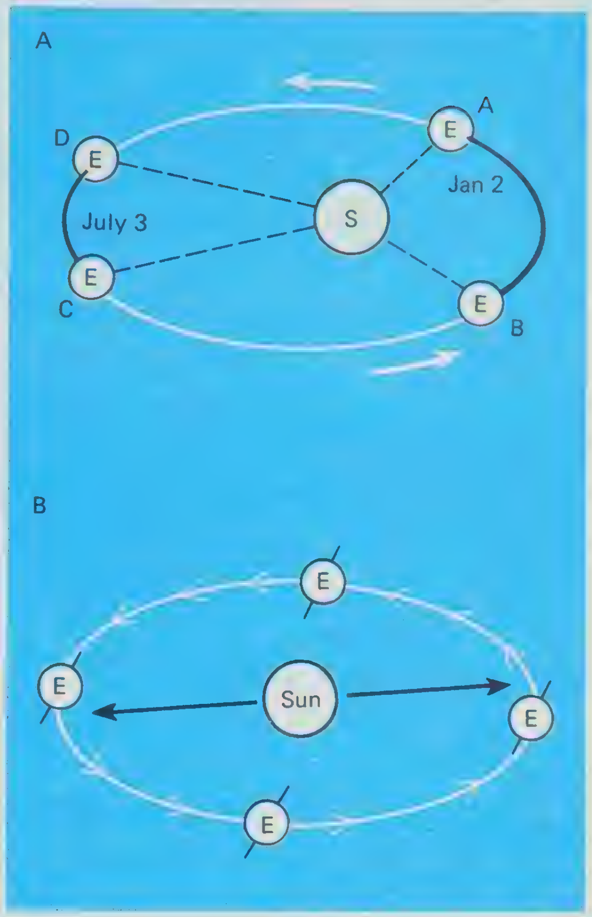


Fig. 85–2

A. The earth travels faster at one end of the ellipse. B. The sun is at one focus of the ellipse. The earth is closer to the sun at one end than at the other end of the ellipse.

7. DIRECTION AND SPEED OF REVOLUTION

How fast does the earth revolve around the sun? Its speed is about 106 200 km/h, or 29.5 km/s. The orbit or path that the earth follows around the sun is an ellipse. The sun is located at one focus of the ellipse as shown in Fig. 85–2A. Therefore, the earth travels faster from A to B (it is closer to the sun) than from C to D (it is farther from the sun). It also means that at one time of the year, on July 3, the earth is farther away from the sun, a distance of 152 000 000 km. On January 2, it has reached the shorter distance, 147 200 000 km. When we say the earth is 149 600 000 km from the sun, we mean an *average* distance.

YOU NOW KNOW

- The earth revolves around the sun in an elliptical orbit at 106 200 km/h.
- At one end of the orbit the earth is 152 million kilometres from the sun.
- At the shorter end the earth is 147.2 million kilometres from the sun.

UNDERSTANDING WHAT YOU HAVE READ

I. What are the two main ideas in Chapter 11?

1. We cannot feel the movement of the earth.
2. The earth rotates on its axis.
3. A pendulum swings in rhythm.
4. The earth revolves in an elliptical orbit.

II. In which paragraph do you find the answer?

1. What did the Foucault experiment prove?
2. What is the speed of rotation?
3. Does the earth move at the same speed at all of its positions in orbit?
4. On what date is the earth closest to the sun?

III. Knowing What and Why

1. Ellipses are drawn
   a. around two points called foci.
   b. around one point to make a radius.
   c. in the form of a triangle.
   d. as two separate circles.
2. Rotation is the same as revolution in all of the following *except* that
   a. they are both earth movements.
   b. neither can be felt by people.
   c. they are both at the same speed per hour.
   d. they are both regular and even.
3. The orbits of planets were explained by
   a. Foucault's pendulum.
   b. Kepler's observations.
   c. Eratosthenes' mathematics.
   d. Newton's prism.
4. Since the orbit of the earth around the sun is an ellipse,
   a. the ellipse causes an eclipse.
   b. rotation slows down.
   c. the earth causes shadows.
   d. the earth's distance from the sun changes.

IV. Finish the story by choosing the missing words from the list below.

The earth, shaped like a (1) is one of the (2) planets. Like the other planets, it (3) light from the sun. It moves in its (4) around the sun, and (5) around on its (6). The motion is from (7) to (8) at a speed of about (9) km/h. Rotation of the earth can be made visible by using a (10).

40 200
nine
west
sphere
east
refracts
rotates
1 700 (at the equator)
reflects
axis
pendulum
orbit

V. Unscramble the scientists' names. Get a singing group.

Answer is on Page 139.

R A E H B
(Tycho)
1
— — — — —

A L G I O E L
(used telescope to see stars)
2
— — — — — — —

O U T F C A U L
(rotation experiment)
3
— — — — — — — —

E T N W O N
(Law of Inertia)
4
— — — — — —

P O L Y M E T
(Theory of earth-centered universe)
5
— — — — — — —

E P L R K E
(orbits of planets)
6
— — — — — —

E E A T T H S O S R N E
(circumference of earth)
7
— — — — — — — — — — — —

Fill in the letters.

— — — — — — —
1 2 3 4 5 6 7

VI. Understanding the Experiments

Fig. 83–1

1. What does the piano stool represent?
2. What is the stool's turning motion called?
3. In which direction does the pendulum swing?

VII. On the Ladder of Understanding

In a single sentence, give the difference between each of the pairs of words.

1. rotation—revolution
2. chromosphere—atmosphere
3. sphere—circle
4. sunspots—sunset
5. petroleum—crude oil

12

TARGET
What do we know about the moon?

The Moon—the Earth's Companion in Space

1. GAZING AT THE MOON

"Shining Bowl in Heaven"
"Watchman of the Night"
"Moon Maiden"
"Man in the Moon"

Man has called the moon by many different names. A few of these names are stated above. The reason that so many names were given to the moon is that it seems to change shape. Some nights it looks like a flat, shiny, full circle. Other nights, it looks bumpy and is only part of a circle. Shapes sometimes seem to appear on its surface.

Ancient men feared the moon. Some worshipped it. Others thought that it brought luck. Still others thought that looking at a full moon could make a person go crazy. The name for such a person was *lunatic* after the Latin word for moon, *luna*. The word LUNAR (LOO-nur) means "of the moon." Let us now see what scientists know about the moon.

2. STUDYING THE MOON

Ancient astronomers spent long nights looking at the moon and taking careful notes. In 1609, Galileo completed careful examination of the moon through his telescope. He announced that the surface of the moon was irregular; that it had plains, canyons and mountains very much like the earth.

Special cameras attached to telescopes have now taken clear pictures of the moon. Special thermometers have checked the moon's temperature. Photos and TV pictures have been taken from space capsules. During the week of May 25, 1969, two American

ASTRONAUTS (as-tro-NAWTS) were taking pictures from a distance of only 16 km from the moon. On July 20, 1969, man walked on the moon for the first time. Thereafter, five more landings were made by astronauts in the Apollo Missions.

3. THE MOON IN RELATION TO THE EARTH

The moon is a companion or *satellite* of the earth. It is our closest neighbor in space. It revolves around the earth. It spins on its own axis. And it travels along with the earth in the solar system and in our galaxy, the Milky Way. In other words, it has the same kind of motions as the earth.

4. STATISTICS OF THE MOON

The moon is a sphere. It has mass and density. It has a circumference, a diameter and a radius. Because the moon's mass, density and size are so much smaller than that of the earth, its gravity pull for any object on it is only 1/6 that of the earth. Fig. 89–1 shows you what happens to an earth weight on the moon.

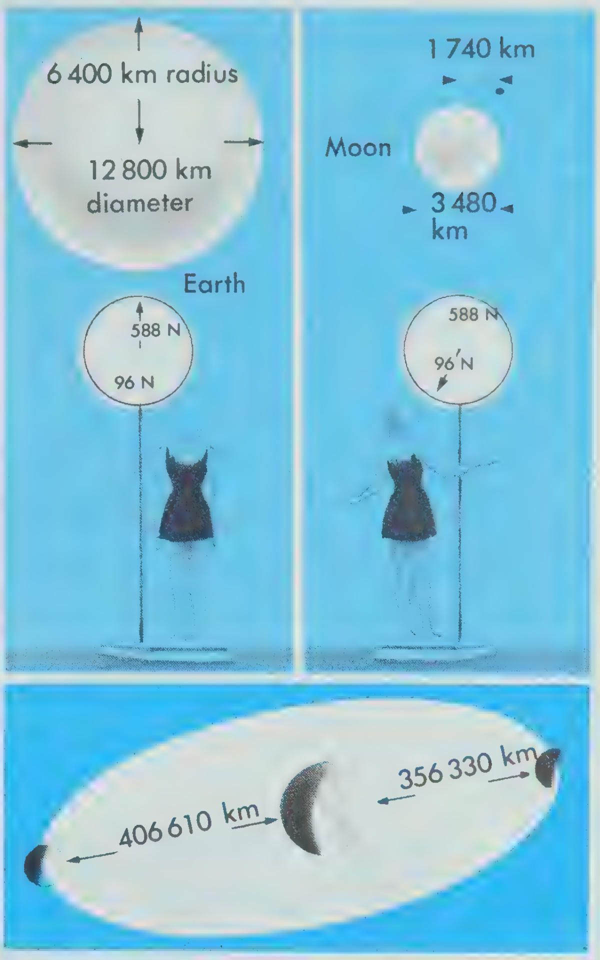


Fig. 89–1

What is the shape of the orbit in which the moon travels? Its distance from the earth varies. Its average distance is 384 330 km.

STATISTICS OF THE MOON

Average distance to earth	384 330 km
Circumference	10 920 km
Diameter through center	3 480 km
Radius to center	1 740 km
Volume	1/50 of earth
Mass	1/81 of earth
Temperature facing full sun ("Day")	+ 110°C
Temperature away from sun ("Night")	– 180°C
Escape velocity	8 573 km/h
Age	About 4 billion, 600 million years

YOU NOW KNOW

- The moon is a satellite of the earth with its own motions.
- The moon's measurements show it is about ¼ the size of the earth, with a gravitational pull about 1/6 of the earth's gravity.

5. THE FACE OF THE MOON

Galileo's telescope studied the TOPOGRAPHY (to-POG-ra-fee) of the moon. He saw towering mountains, smooth plains, valleys and deep round holes called CRATERS (KRAY-turs). The view was very clear and the studies were made very carefully. At one time, astronomers thought that the large, dark areas were seas, filled with water. We now know that there is no water on the moon. The difference in appearance comes from the different kinds of materials. The moon's seas are called MARIA (MAH-ree-uh). It is from the Latin word MARE (MAH-ray) whose plural is maria. Another reason is the way the surface of the moon reflects the sunlight. If water were present, the reflection would be different.

How were the craters and mountains formed? One theory is that the moon was bombarded with falling meteors from space. As these meteors fell, they dug huge holes. Another theory is that the craters were formed by

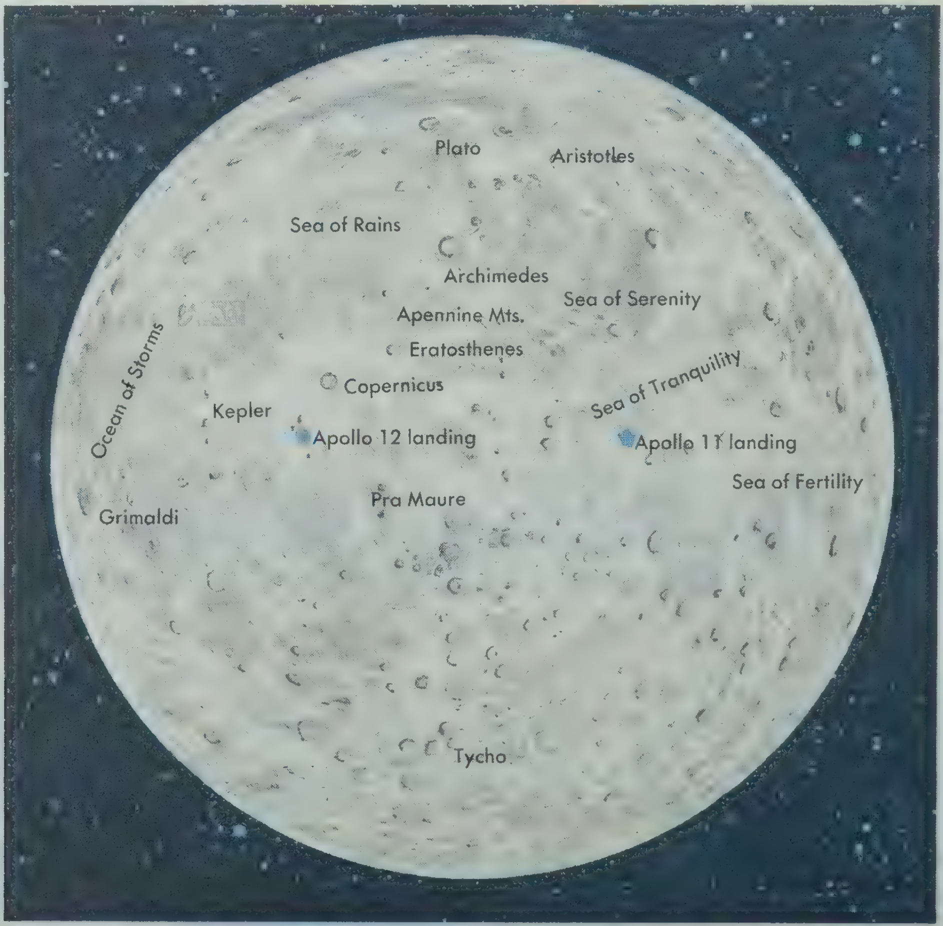


Fig. 90–1

This is a typical map of the moon. Many places are named after scientists. Some are named for earth spots.

lunar volcanoes. This theory may be more accurate than was previously thought. The sharp changes in temperature from "night" to "day" (see Table, Page 89) probably cause the rock to crumble. There are also *moon* quakes which may cause tumbling and moving of the rocks and fragments.

6. THE TOPOGRAPHY OF THE MOON

There are about 30 000 craters visible through the telescope. Some craters have wide, flat floors. Some have lofty central peaks. The craters named Copernicus, Newton and Tycho are among the largest. Some stretch from 80 to 240 km from one rim to the other. The crater Copernicus has a diameter of 90 km.

The "seas" are also very wide. Mare Imbrium (MAH-ray IM-bree-um) is the "Sea of Showers" and stretches 1 130 km from one "shore" to the other "shore." Mare Imbrium is usually called the central sea. Other well-known seas are: the Sea of Serenity, in the west; the Ocean of Storms, in the east; and the Sea of Clouds, in the southeast. Imbrium, by the way, is the "right eye" of the "Man in the Moon."

7. IS THERE AN ATMOSPHERE ON THE MOON?

When the moon passes in front of the stars, their light is "snapped off" suddenly. There is no flickering. An atmosphere would make the star flicker. This shows that there is no atmosphere on the moon.

There is another reason for doubting the presence of a moon atmosphere. Look back at the Chart in Paragraph 4. You see that the moon has a certain *escape velocity*. What does this mean? If you shoot a bullet straight up above into the sky, it will always be returned to earth by the force of gravity. To get a bullet or a rocket to escape into space from the surface of the earth, it must travel at a speed of about 40 200 km/h. This speed is called the escape velocity. But the moon's gravity force is much weaker than the earth's. Therefore its escape velocity is only 8 573 km/h.

Since the escape velocity is so small, scientists believe that molecules of air and water would "dance" right off the moon and escape. They think that even if there had ever been water or air on the moon, it must have escaped long ago. The answer for the present is: no atmosphere.

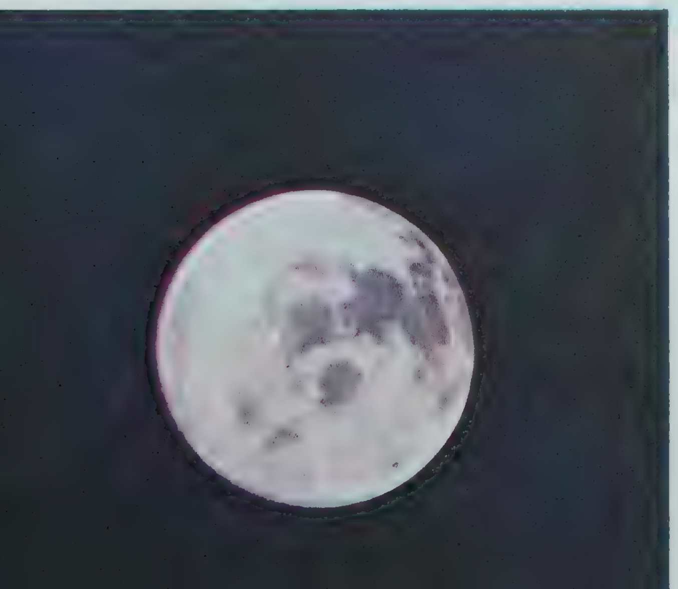


Fig. 91–1

What do the lunar missions tell us? The dark areas are covered by a volcanic rock—*basalt*. The highland rocks are *feldspar* and are rich in aluminum. Carbon, the "element of life," is very rare.

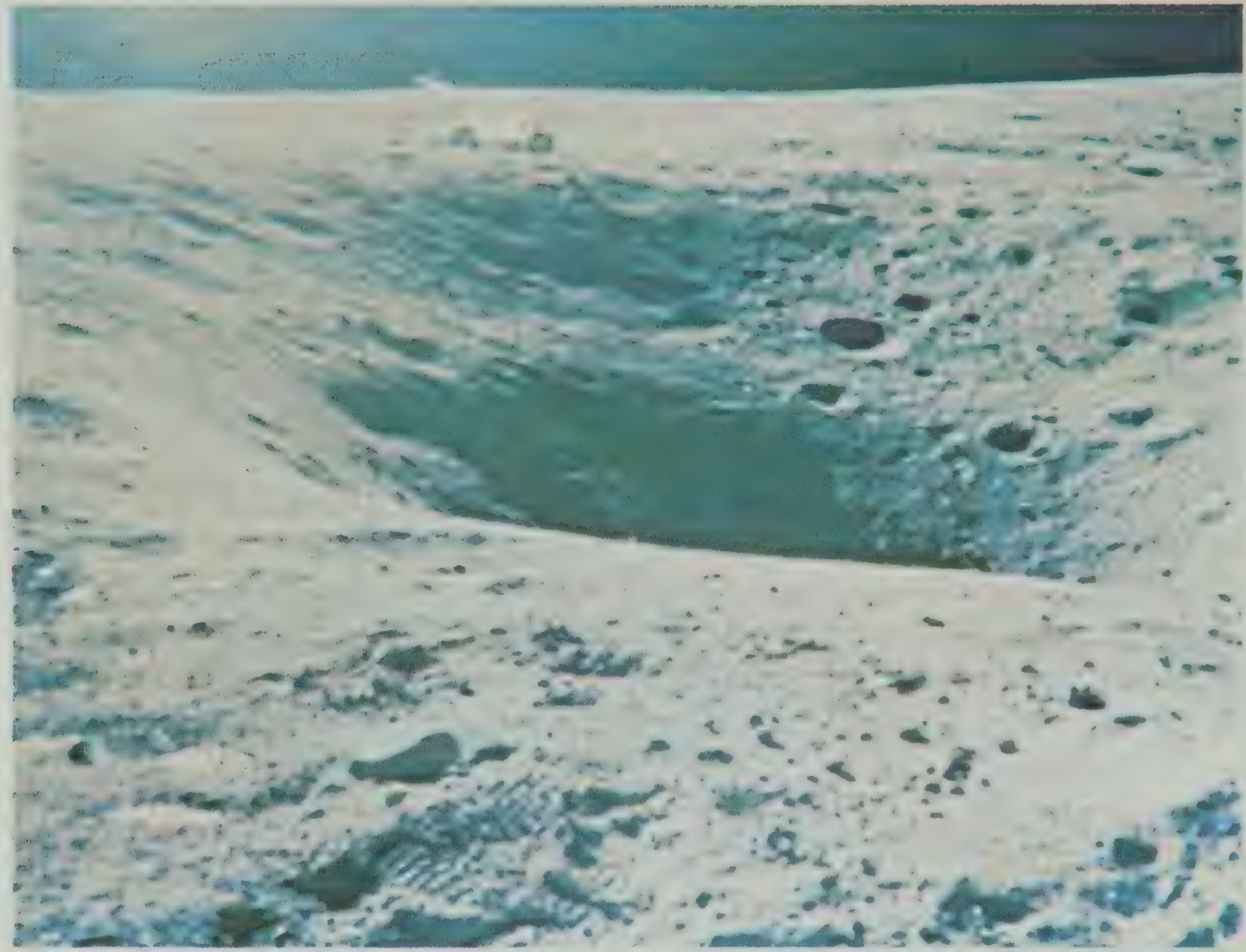


Fig. 92–1

This picture of the surface of the moon was taken by a camera in an unmanned spacecraft that landed on the moon.

SAMPLES OF MOON ROCKS

- *Genesis Rock* (from Apollo 15). It is a mineral called ANORTHOSITE (uh-NOR-thuh-syt). It has been "dated" to be about 4 billion years. It is also found on earth.
- *"Orange Soil"* (from Apollo 17). This is not rust, as was first thought; it is a glassy basalt, tinted orange by titanium. It was formed about 3.7 billion years ago from molten rock out of a volcano.
- *KREEP*—a rock type not known on earth. This is quite radioactive. It gets its name from: potassium (K), rare (R), earth (E), elements (E), and phosphorus (P).

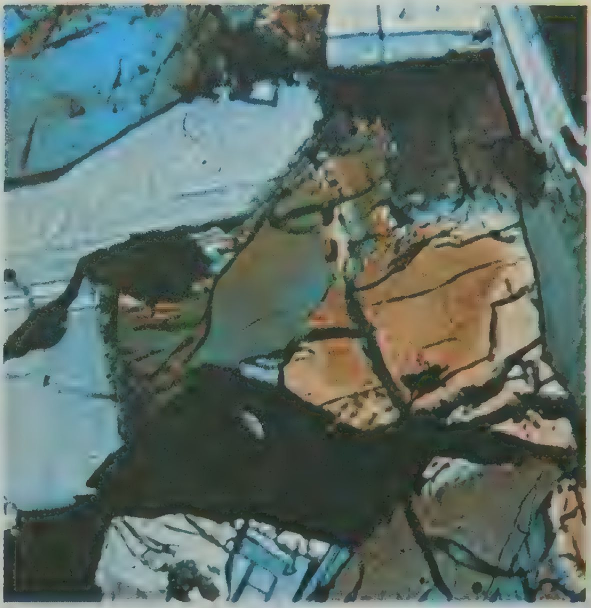


Fig. 92–2
Lunar basalt as seen under a microscope. These form the dark-colored maria.

YOU NOW KNOW

- The face of the moon consists of mountains, valleys, plains, craters and dark spots called seas.
- The material of the moon is probably hard, with some dust.
- There is no gaseous or water atmosphere on the moon.

UNDERSTANDING WHAT YOU HAVE READ

I. What are the two main ideas in Chapter 12?

1. The moon is a satellite of the earth.
2. Mountains on the moon can be located by camera.
3. The moon is a sphere which reflects light and seems to have no atmosphere.
4. The moon's craters are very wide.

II. Explanation, Please . . . answer in one or two sentences.

1. Who first described the surface of the moon?
2. Have men walked on the moon?
3. Why do objects on the moon weigh less than on the earth?
4. Why do we think there's no water on the moon?

III. Knowing What and Why

1. Escape velocity depends on the
   a. pull of gravity.
   b. extremes of temperature.
   c. rate of rotation.
   d. density of the atmosphere.
2. When the moon faces the sun, its
   a. temperature drops sharply.
   b. escape velocity disappears.
   c. temperature is enough to boil water.
   d. orbit changes.
3. The Sea of Showers on the moon
   a. has no water in it.
   b. has liquid hydrogen in it.
   c. does not really exist.
   d. is the same as the Sea of Tranquility.

IV. True or false? Explain your answer.

1. If men landing on the moon find pumice, it will strengthen the theory of the presence of volcanoes.
2. Even if the seas on the moon were once filled with water, they are now dry.
3. It is easier for a capsule to leave the moon, than for the same capsule to leave the earth.

V. Number, Please . . .

1. You would need ________ moons to make up the volume of the earth.
2. The diameter of the moon is ______ ______ (what fraction) of the diameter of the earth?
3. 38 000 km is ____________ .
4. 149 600 km is ____________ .
5. The earth has ____________ satellites.
6. The sun has ________ planets orbiting around it.

13

TARGET
Why does the moon look different during the month?

The Views of the Moon

1. LOOKING BACK . . .

Why do we see the moon? It is not a luminous body; it does not glow. Its light, like that of the planets, is light reflected from the sun. Sunlight, reflected from the moon, produces *moonshine*. Sunlight, reflected from the earth, produces *earthshine*. It is estimated that only about 7% of the sunlight that falls on the moon is reflected. Some of this 7% light which strikes the earth is changed to radiant heat.

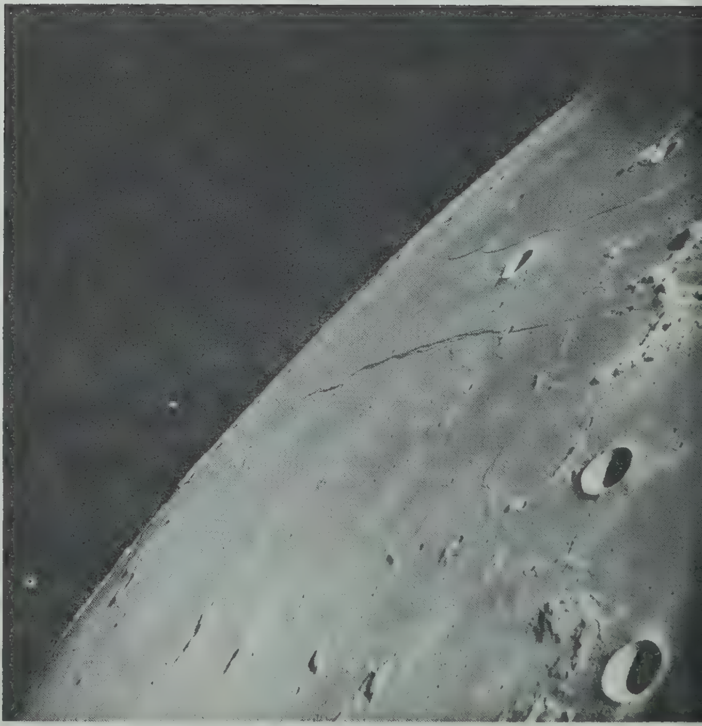


Fig. 94–1

This is a picture of the front side of the moon when sunlight is shining on it.

2. MOTIONS OF THE MOON

As you saw before, the moon spins on its axis (rotates) and moves about

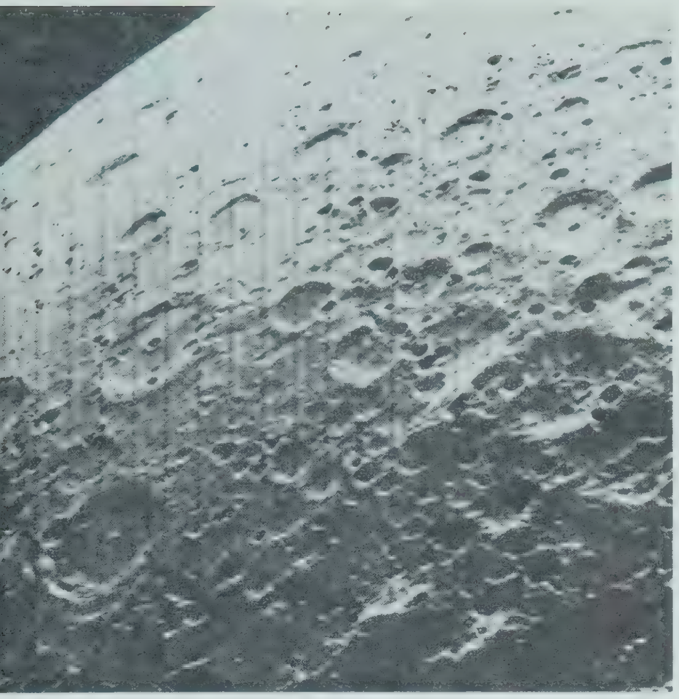


Fig. 95–1

Since 1959, several satellites and astronauts have gotten a good look at the back of the moon, never seen before that time. It is not very different from the front side of the moon.

the earth (revolves). How long does it take the moon to rotate on its axis? How long does it take the moon to make one revolution around the earth? And what are the results of these motions? To help find the answers to these questions, do the following experiment.

DO AND DISCOVER

Investigation 5: What are the moon's motions?

1. Draw a very large circle on a sheet of newspaper (Fig. 95–2). This is the path of the moon around the earth. Draw a smaller circle in the center to represent the earth.
2. Draw in the numbers as shown in Fig. 95–2. Place a teacup on Number 1 with its handle facing the earth. The handle represents the face of the moon.
3. Move the cup around the earth slowly so that the handle (the "face") is always towards the earth. When the cup returns to spot Number 1, it has made *one* rotation on its axis and *one* revolution in its orbit. If you were on the "earth," you could never see the back of the cup ("moon").

From this experiment, you can see why we have never seen the back of the moon from the earth. Notice, we said "from the earth." Russian satellites took the first photos of the back of the moon in 1959. Later, American satellites took similar pictures. And now our astronauts in our Apollo space missions have photographed it again. To no one's surprise, the back looks very much like the front!

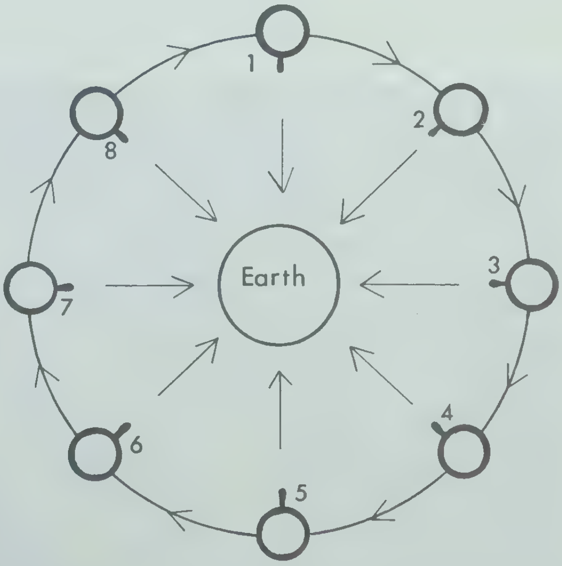


Fig. 95–2

How does this diagram explain why we have never seen the back of the moon from the earth?

THE MOON DAY

FULL DAY
IS 27.3
EARTH DAYS

DAYTIME: 14 EARTH DAYS
NIGHTTIME: 14 EARTH DAYS

The experiment (Fig. 95–2) also shows you that the time it takes for one rotation is the same as the time for one revolution. They are both 27.3 d. This measurement is in reference to a star. You will see later that it is 29.5 d when we use the sun as a reference point.

3. NIGHT AND DAY ON THE MOON

Just as there is night and day on the earth, there is night and day on the moon. Just like the sun, the moon rises (appears) in the east and sets (disappears) in the west.

It takes the moon 27.5 *earth days* to rotate once on its axis. This is a *moon day* (a lunar day). If you were standing on the moon, the sun would rise "at daybreak" and would be seen for about 14 d (half of 27.3). A day on the moon is two earth weeks! Then the sun would set and there would be about 14 earth days of darkness.

4. TIMETABLE FOR THE MOON

Many newspapers print a timetable to show when the moon rises each day and when it sets. Does the time change? Yes. If you were to watch

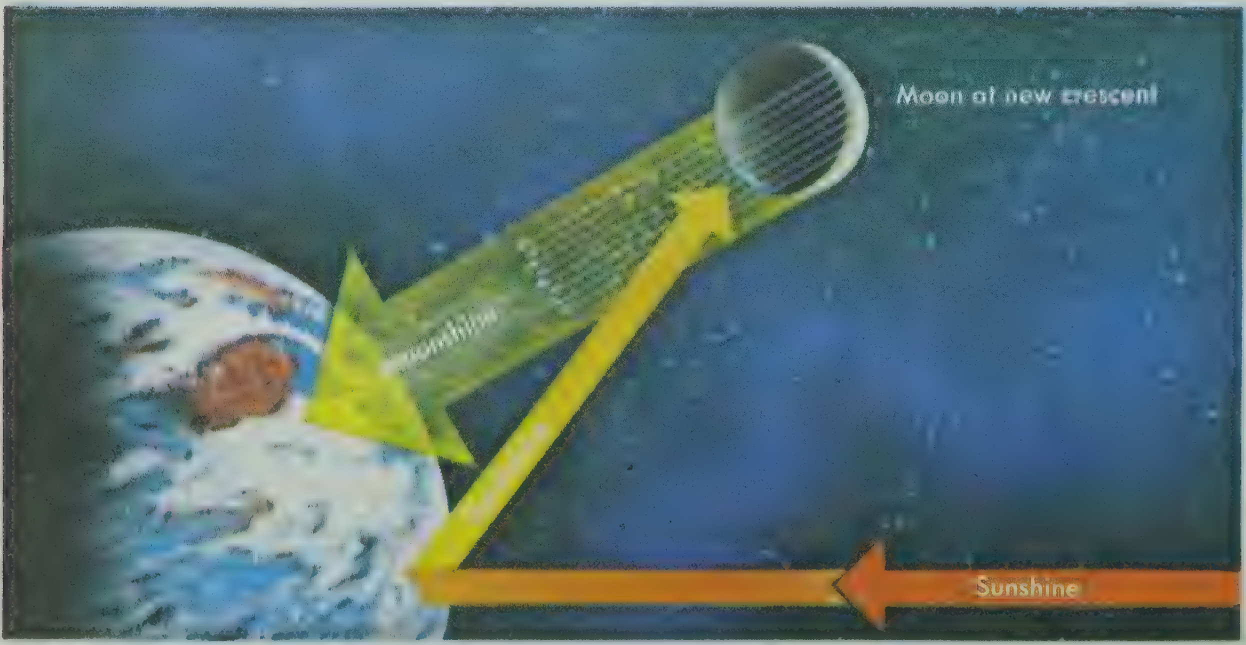


Fig. 96–1

Where does the moon get its light? What do we see when we see moonlight?

the moon, night after night, you would soon see that the moon appears to rise about 50 min later each day. You started to watch the moon rise at 7:00 p.m. on the first night. Each night you would see it 50 min later. Soon, you would be seeing the moon in the early morning; then in the middle of the day; then in the late afternoon. At the end of the month, about 29 d later, the moon would rise again at 7:00 p.m.

Can you see the moon in the daytime? Of course! When the moon is on the same side of the earth as the sun, it appears mostly in daytime. When the moon is on the opposite side, you see it mostly at night.

YOU NOW KNOW

- The moon revolves once around the earth in 27.3 d; it also rotates once on its axis in 27.3 d.
- The lunar day is 27.3 earth days, with about 14 d of daylight and about 14 d of darkness.
- The moon travels from west to east with the earth. It rises 50 min later each day.

5. WHY IS THE MOON LIT UP IN SECTIONS?

The moon shines by reflected light from the sun. When the whole side of the moon is lit up, we say it is a *full moon*. As you watch the full moon, night after night, you will see that the view changes. It grows "smaller" and "smaller"; then "it fades away." Later, you see the opposite happen. Small sections of the moon appear; the sections grow larger. And then, 29.5 d later, there is a full moon again. The changes in the appearance of the moon during a month are called the moon's PHASES (FAY-ziz). Figs. 98–2, 98–3, 99–1, 99–2 show the different phases and their names.

6. HOW ARE THE MOON'S PHASES FORMED?

The phases are formed because different amounts of the illuminated moon are seen from the earth.

DO AND DISCOVER

Investigation 6: How can we show the phases of the moon?

1. Darken the classroom. Place a black slate globe on a table in the center of the room. This represents the moon. At the side of the room, place a projector on a table to represent the sun. Remove the ocular lens from the projector. Adjust the light so that a complete half of the slate globe is lit up.
2. All pupils arrange themselves in a circle around the room. Each pupil carries a sheet of paper and pencil with him. The paper has been ruled with eight circles as shown in Fig. 98–1.
3. The pupils circle slowly around the moon to see the phases. Each time they come to one of the numbered positions, they stop. Then they shade in that part of the moon that is *not* lit up.
4. Now compare the drawings with those in Fig. 98–1.

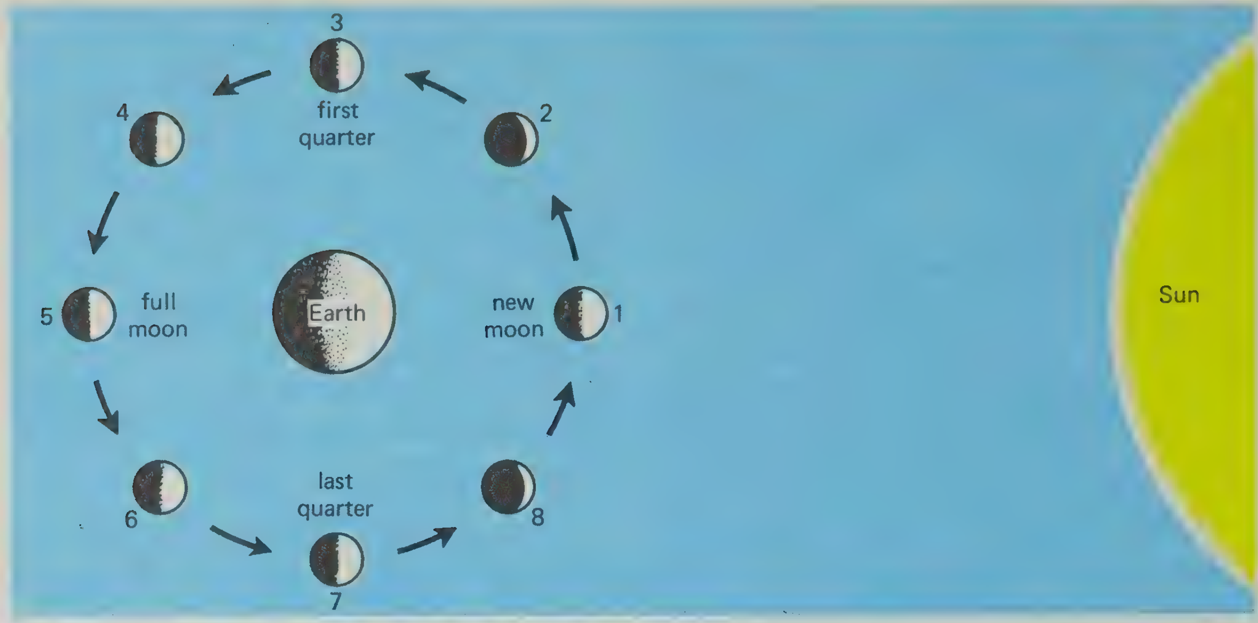


Fig. 98–1

When the moon is between the earth and the sun, we see none of the moon (new moon). When the moon is on the opposite side of the earth, we see the full side of the moon lit up, or illuminated. This is the full moon.

Summary of the Moon's Phases

Phase	*Description*
New Moon (Fig. 98–2)	The moon cannot be seen from earth because the illuminated part faces away from earth. The new moon rises at sunrise and sets at sunset.
First-Quarter (Half-moon) (Fig. 98–3)	One-half of the illuminated part of the moon can be seen from earth. The moon rises at noon and sets at midnight.

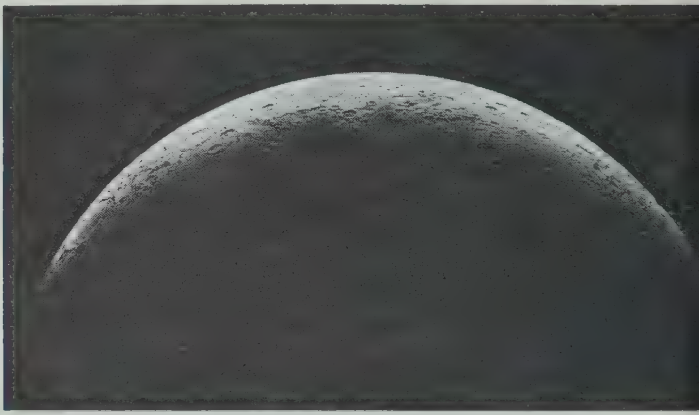


Fig. 98–2

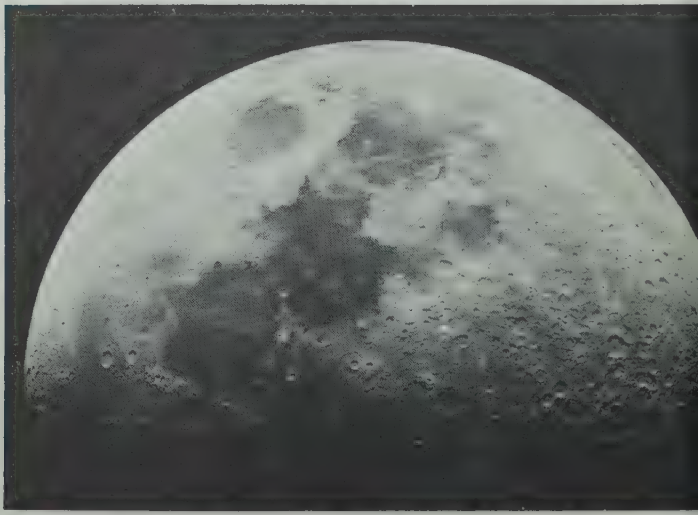


Fig. 98–3

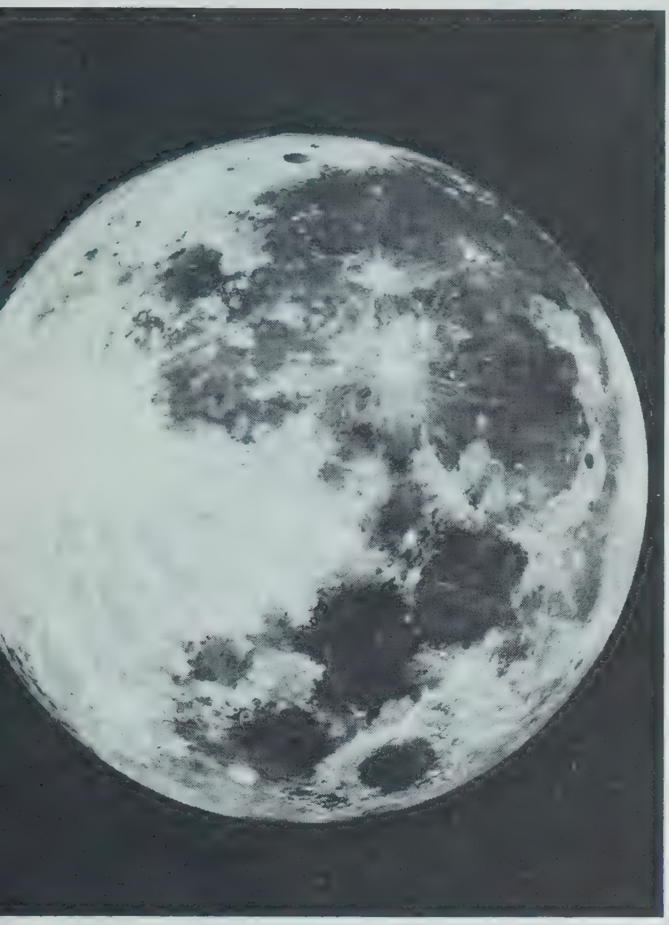


Fig. 99–1

Full Moon The entire illuminated half of the moon can be seen from earth. The full moon rises at sunset and sets at sunrise.

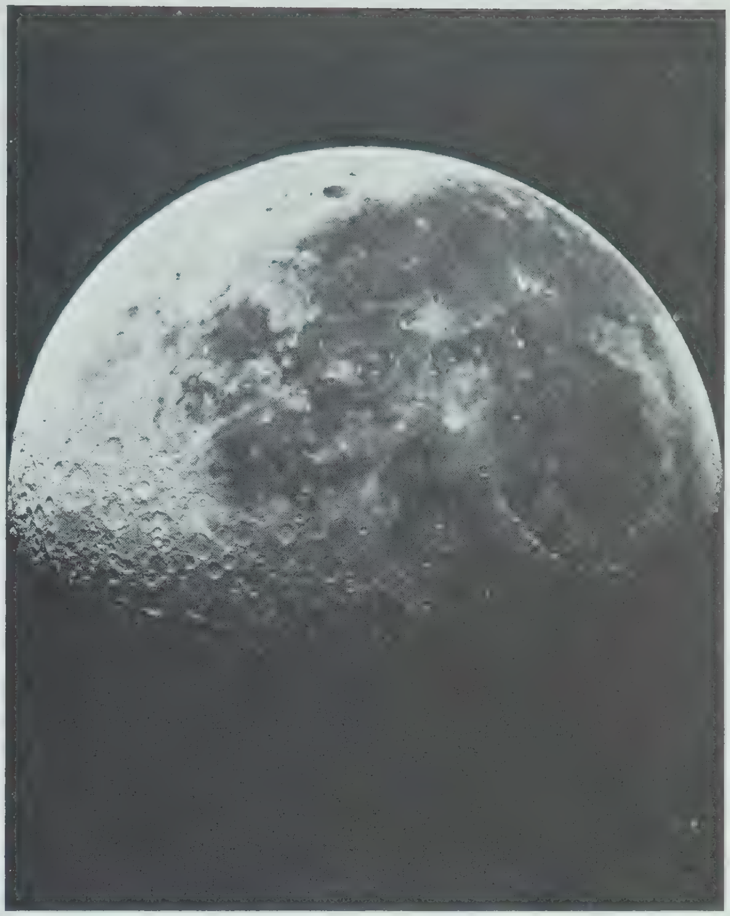


Fig. 99–2

Last-Quarter (Half-moon) One-half of the illuminated half of the moon is visible. The moon rises at midnight and sets at noon.

UNDERSTANDING WHAT YOU HAVE READ

I. What are the two main ideas in Chapter 13?

1. The appearance of the moon depends on its position in orbit.
2. Moonlight is reflected light from the sun.
3. The motions of the moon are regular.
4. Satellites have taken photos of the moon.

II. In which paragraph do you find the answer?

1. Does the moon rise at the same time each day?
2. How much of the moon do we see at new moon?
3. How long is daylight on the moon?
4. Why can we sometimes see the moon during the day?

III. Knowing What and Why

1. At quarter-moon, we see
   a. one-half of the new moon.
   b. one-half of the full moon.
   c. a crescent.

   - d. one-quarter of the full moon.
2. From full moon to full moon is about
   - a. 29.5 d.
   - b. 14 d.
   - c. 7 d.
   - d. 365.25 d.
3. The time of rotation of the moon
   - a. is double the time of any phase.
   - b. one-half the time of a lunar month.
   - c. equal to its period of revolution.
   - d. changes with gravity.
4. Each day, the moon first appears in the sky
   - a. in the west.
   - b. in the east.
   - c. near the North Star.
   - d. in no special place.

IV. True or false? Explain your answer.

1. Moonlight is really sunlight.
2. Astronauts can see earthshine.
3. During the day, we can never see the moon.

V. Complete the statements by choosing the correct word or phrase from the parentheses.

1. The moon rises 50 min (later, earlier) each day.
2. Twenty-nine and one-half days refers to (first-quarter to third-quarter, new moon to new moon).
3. At this time, scientists think the back of the moon is very much (like, different from) the front of the moon.
4. The amount of sunlight reflected by the moon is about (7%, 77%).

VI. For the Artists and Craftsmen

1. Copy Fig. 98–1 (Phases of the Moon) onto a large poster board. Label all parts. Bring it to class.
2. Make a model of the moon and earth. Use a basketball for the earth, a tennis ball for the moon. Use a wire hanger to attach the "moon." Demonstrate rotation, revolution and phases.

VII. For the Amateur Scientists

1. Do you own a camera with a time exposure? If so, you can photograph the moon. Slant the camera on a table. Center the moon in your viewer. Expose your film for 10 s.
2. Observe the moon each night for 29 d. Draw what you see. Compare your observations with the phase charts given in your daily newspaper or on a calendar.

VIII. Extending Your Learning

1. In the dictionary look up the meanings of CRESCENT (KRES-unt) and GIBBOUS (GIB-us). Write the definitions in your notebook.
2. Now look at Fig. 98–1. In your notebook draw the two gibbous phases and the two crescent phases.

TARGET
What causes the tides in the oceans?

Rising Tides and Falling Tides

1. "TIME AND TIDE WAIT FOR NO MAN"

This ancient saying means simply that no one can start, stop, speed up, or slow down the passing of time nor the action of the tides. Ancient people watched the rise and fall of tides. Boats sailed out with high tides. Precious shellfish were collected at low tide. It did not take sensible people very long to see that the rise and fall of tides was a *regular* process. In other words, tides could be timed and they could be predicted.

2. HIGH TIDE AND LOW TIDE

Your comfortable, dry place at the beach, close to the water, may become uncomfortable. For, as you have noticed, the ocean water rises as the *tide* "comes in."

If you observe the beach carefully, from day to day, you soon discover that there are *two* high tides a day and two *low* tides a day. Fishermen and boating people know that the height of tides varies in different localities.

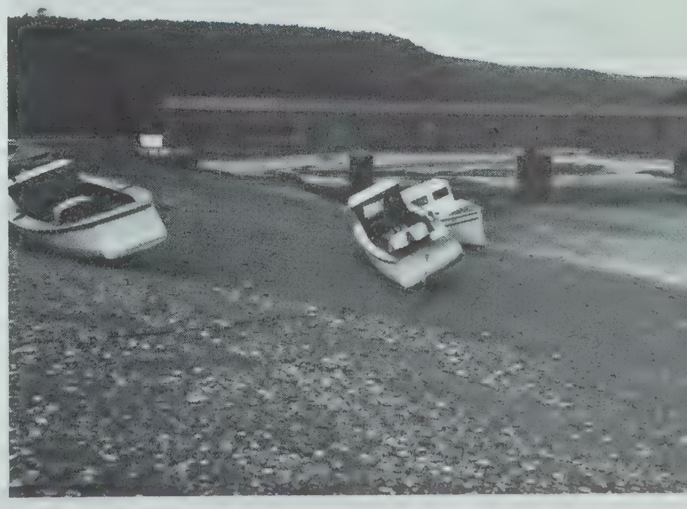


Fig. 101–1

This is the Bay of Fundy in Canada. Why are the boats out of the water?

The difference between low tide and high tide is called the *tidal range*.

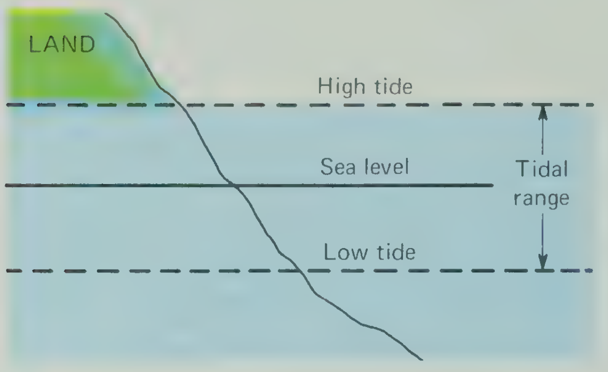


Fig. 102–1

In New York, the range is 1.5 m. In the Bay of Fundy, Canada, the range is 15 m.

3. TIDE TABLES

If you were to keep careful records of your observations, you could draw up a tide table for your area. You would then find that each tide lasts about 6 h and 13 min. Your table would also show you that the high tide comes about 52 min later each day. If you were to keep a record of the time when the moon rises, you would find that this also happens 52 min later each day.

Now suppose you had a friend in a spot exactly opposite to you on the other side of the earth. And suppose that he, too, kept records. If you compared your records, you would find that when you saw a high tide, he saw a high tide. When he recorded a low tide, you recorded a low tide.

Secondly, if you also recorded the phases of the moon, you would discover that the tides are much higher twice a month. This occurs at full moon and at new moon. Tide tables tell you when the tides rise and fall. Let us see why.

SAMPLE TIDES IN NEW YORK

Sandy Hook

	High	Low
August 7	2:54 A.M.	10:06 A.M.
	3:24 P.M.	11:06 P.M.
August 8	3:54 A.M.	11:00 A.M.
	4:24 P.M.	11:54 P.M.
August 9	4:54 A.M.	11:48 A.M.
	5:18 P.M.	12:48 A.M.

SAMPLE TIDES IN THE BAY OF FUNDY, CANADA

Saint John, New Brunswick

	High	Low
August 1	10:05 A.M.	3:55 A.M.
	10:20 P.M.	4:15 P.M.
August 2	10:50 A.M.	4:40 A.M.
	11:00 P.M.	5:00 P.M.
August 3	11:35 A.M.	5:15 A.M.
	11:50 P.M.	5:35 P.M.

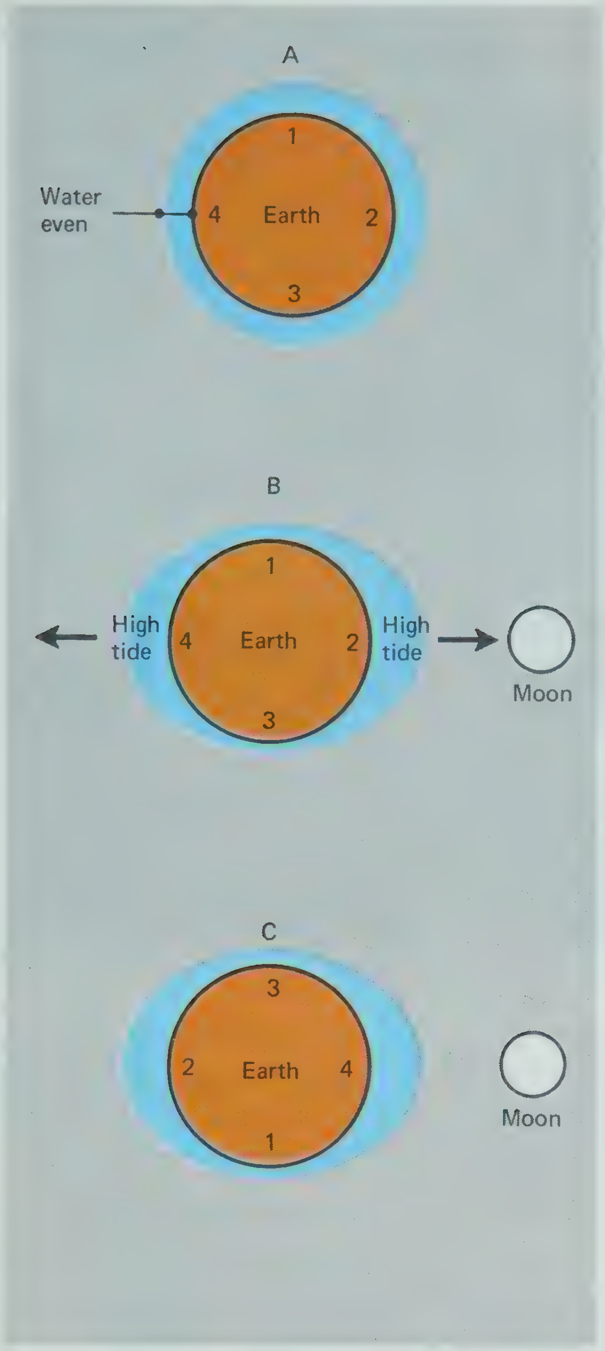
Yarmouth, Nova Scotia

	High	Low
August 1	8:55 A.M.	2:50 A.M.
	9:05 P.M.	2:55 P.M.
August 2	9:30 A.M.	3:30 A.M.
	9:45 P.M.	3:35 P.M.
August 3	10:20 A.M.	4:00 A.M.
	10:25 P.M.	4:20 P.M.

Tide tables are issued to guide fishermen and ship captains. What happens to the time of the tides each day?

4. WHAT CAUSES THE DAILY TIDES?

Let us keep two things in mind. First, the rise and fall of tides follow a *regular* timetable. Secondly, their timetable resembles the timetable of the moon. Therefore, we must find our explanation for tides by understanding the motions of the moon. The



A

If there were no gravity pull of the moon and sun the water would be evenly distributed all around the earth.

B

The moon pulls on the earth at Point 2. The water rises to high tide at 2. The water on the opposite side also rises as the earth is pulled away from it. At Points 1 and 3, the water falls for a low tide.

C

6 h and 13 min later, the earth has rotated under its waters. Points 1, 2, 3, 4 are in new positions. Points 2 and 4 had low tides. Now 12 h and 26 min later, Points 2 and 4 have their second high tide.

Fig. 103–1

earth rotates on its axis and the moon revolves around the earth in a regular pattern. That explains why tides are regular. We know that both the earth and the moon have gravitational pull. That explains the lifting of the waters.

Now look at Fig. 103–1. Follow the diagram from A to C and you will understand the causes of the tides.

YOU NOW KNOW

- A tide is the regular rise and fall of ocean water.
- Daily tides are caused mostly by the gravitational pull of the sun and the moon on the waters of the earth.
- At most spots in the world, there are two high tides and two low tides every day.

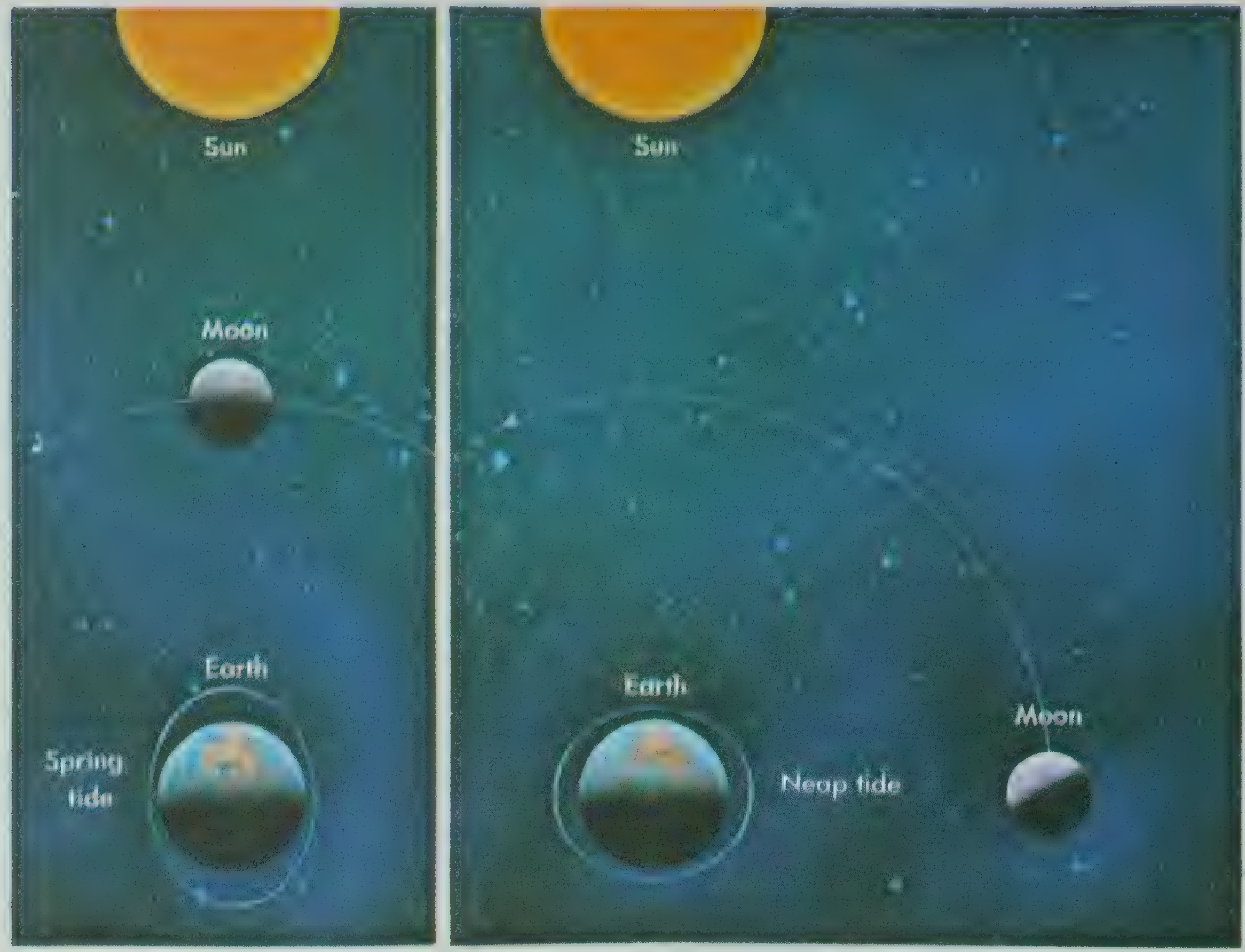


Fig. 104–1

A. When the sun and moon are in a direct line, the tidal range is very high. This is the *spring tide*. B. At first-quarter and last-quarter, the moon and sun are at right angles. The force of the sun and the force of the moon work *against* each other. Now the tides are not quite so high, and not quite so low. This is the *neap tide*. This is caused by gravitation.

5. THE SUN ALSO CAUSES TIDES

You certainly remember that the sun also has a gravitational pull on the earth. Should not the sun also cause tides? Look back in Paragraph 3. Your records and your friend's records showed an extra-strong tide twice a month; at new moon and at full moon. Of course, the sun is very far away from the earth, compared to the moon. Its gravitational pull on the earth is therefore weaker. But it is there, and it certainly pulls on the earth's waters. Let us follow this idea in Fig. 104–1.

6. ARE TIDES ALWAYS ON TIME?

If the shores were all even and the topography of the ocean floor were smooth, tides would be far more punctual. However, there are large canyons under the ocean and sandbars sticking up out of the ocean. These sandbars and canyons slow down the tides. Therefore, the rising tide varies from place to place.

7. IS A KNOWLEDGE OF TIDES USEFUL?

Shipping and boating sports time their activities according to the tides. Tugs which pull huge freighters and passenger liners out of the harbors into the deep oceans, take readings of the tides. Fishermen time their catching to follow the tides, since certain fish are brought in with the tides. There have been many experiments in trying to harness the power of the tides to run generators and turbines. While there has been some success, it is still not a very widely used method.

SUMMARY OF TIDES		
Daily Tides (4 each day)	High Low High Low	Each separated by a time period of about 6 h, 13 min
Spring Tides (2 each month)	Full Moon New Moon	About 14 d apart
Neap Tides (2 each month)	First-Quarter Last-Quarter	About 14 d apart

UNDERSTANDING WHAT YOU HAVE READ

I. What are the two main ideas in Chapter 14?

1. Tides can destroy property.
2. Tides are the regular rise and fall of ocean waters.
3. Fishermen watch the tides.
4. Tides are controlled by the moon and the sun.

II. In which paragraph do you find the answer?

1. Does the sun control tides?
2. How can we predict when tides will come?
3. What is the tidal range?
4. What is a neap tide?

III. Knowing What and Why

1. When it is high tide on one side of our globe, the opposite side has
   - a. a low tide.
   - b. a high tide.
   - c. a neap tide.
   - d. an ebb tide.
2. Tides are caused mostly by the
   - a. revolution of the earth.
   - b. rotation of the moon.
   - c. rotation of the earth, plus gravity of the moon.
   - d. magnetic effects of the earth.
3. Sandbars and bays
   - a. slow down the tides.
   - b. speed up the tides.
   - c. have no effect.
   - d. cause neap tides.
4. Neap tides
   - a. are stronger than spring tides.
   - b. are weaker than spring tides.
   - c. are artificial tides for generating electricity.
   - d. come regularly, with every spring.

IV. Choose the words from *Column B* which best match the words in *Column A.*

A

1. neap tides
2. rotation period
3. tidal range
4. earthshine
5. Foucault
6. spring tides
7. U.S. photos of back of moon
8. crescent

B

a. low tides
b. reflected light
c. low point to high point
d. moon phase
e. 24 d
f. Luna 9
g. Apollo 10
h. high tides
i. pendulum
j. 27.3 d

V. Unscramble the letters. Answer is on Page 139.

PHRSEE
1
(shape of the earth) — — — — — —
IEDT
2
(high water) — — — —
HEPSA
3
(section of lighted moon) — — — — —
CESCTNRE
4
(smallest phase of moon) — — — — — — — —
BTROI
5
(elliptical path of earth) — — — — —

Fill in the numbered letters. Get the name of a musical instrument.

— — — — —
1 2 3 4 5

VI. For the Collectors

Write to the U.S. Coast Guard, Washington, D.C. or to Canadian Coast Guard—Central Region, 1 Yonge St., Toronto, Ontario. M5E 1E5. Ask for free tide tables for the harbor nearest your home.

VII. For the Language Experts

Choose twenty (20) new words which you have learned so far in this book. List them in column form as shown. Then look up the Spanish and French equivalent.

English Word	*Spanish*	*French*

15

TARGET
How do shadows change the appearance of the sun and the moon?

Eclipses Are Caused by Shadows

SCIENTISTS AWAIT ECLIPSE OF SUN

MANITOBA, July 19—Astronomers, amateur sky-gazers and laymen from all over the world are waiting for a rare and beautiful sight—tomorrow's total eclipse of the sun.

The eclipse of the sun will start in New York City at 4:41 p.m. and end at 6:50 p.m. At 5:49 p.m., 89 percent of the sun will be covered by the shadow of the moon. This will be the maximum eclipse that will be able to be seen from New York City.

WARNING!

Eyes can be permanently damaged by looking at the sun directly, even through sunglasses, overexposed film negatives or smoked glass. For the right way to see the eclipse, read the next paragraph.

The best way to see the eclipse is to watch it on TV or by a homemade projection device. This consists of two pieces of cardboard, one with a pinhole in it. Stand with your back to the sun and focus the image of the sun through the pinhole so that you can see it on the other piece of cardboard. *Never look through the pinhole at the sun directly.*

JULY 20, 1963 . . . THE SUN GREW DARK

July 20, 1963 was a great day. It was a day on which the sun grew dark in the middle of the day! Millions of people all over North America saw this great show in the heavens. It was a *total solar eclipse*. This great event comes only about 50 times in a century (100 years). There was another total solar eclipse March 7, 1970, and one in 1973. The last solar eclipse in this century will be in 1999.

If you had been living in the year 1263, the sight of the eclipse may have brought a different feeling. People might have trembled and feared the worst. Their superstition and their ignorance might have told them that evil spirits had invaded the sun to frighten the people. But, of course, that was 700 years ago. Today we know the cause of eclipses. We can predict their coming to the second. Let us find out about eclipses.

2. WHEN LIGHT IS BLOCKED

We know that when light strikes an opaque object, it is stopped. The object which blocks the light forms a dark area behind it. The object appears as a *shadow*.

DO AND DISCOVER

Investigation 7: How are shadows formed?

What you do:

These experiments are to be done in a dark room.

A. Remove the ocular (focusing) lens from a projector. Shine the light of the projector on a white wall or screen about 2.5 m away. Hang a tennisball from a string in the path of the light. Observe the shadow on the screen.

B. In the same way, form shadows with a soft ball; a Ping-Pong ball; a square cardboard 8 cm × 8 cm × 8 cm; and a clown cut from cardboard. Observe the shadows.

C. Repeat each experiment in B but change the distance of the object from the light.

What you see:

1. All of the opaque objects form shadows on the screen.
2. The shadows are the same shape as the object which blocks the light.

What you learn:

1. What happens to shadows as the blocking object is moved farther from

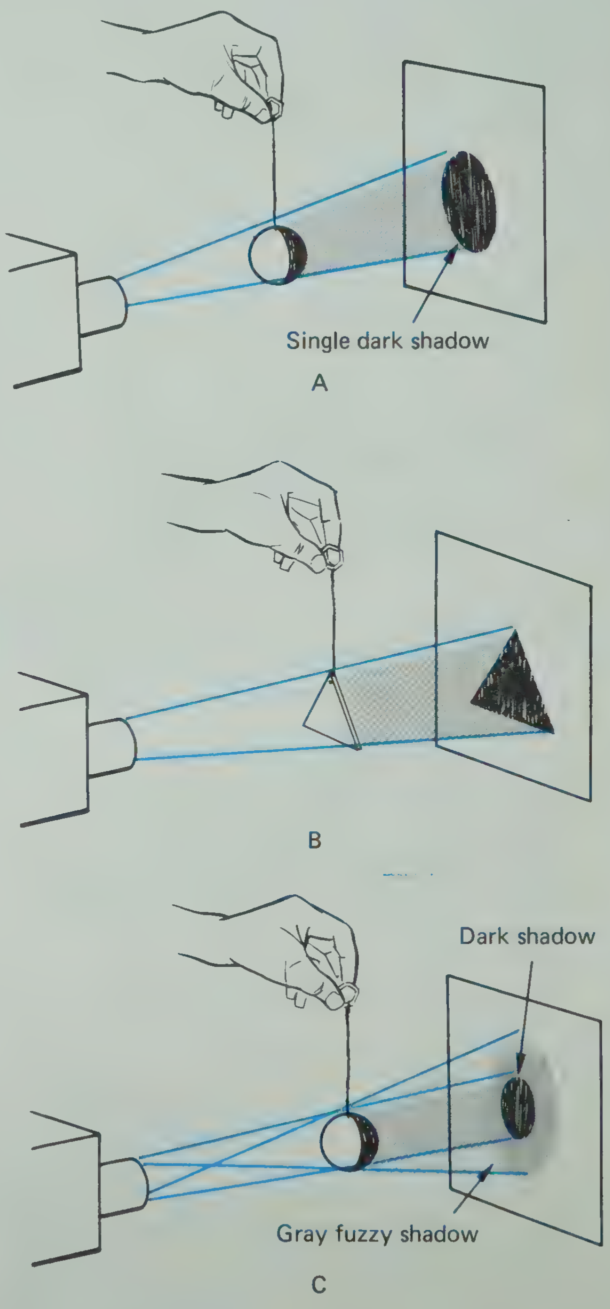


Fig. 108–1

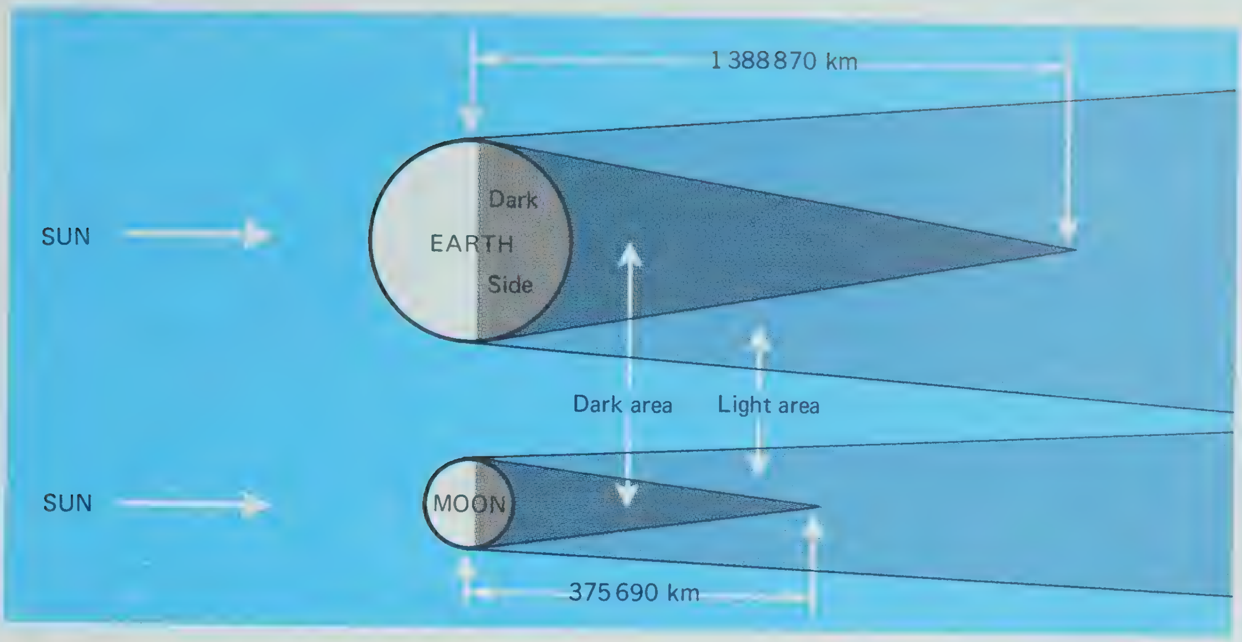


Fig. 109–1

The earth and the moon are both opaque, spherical bodies in space. They absorb light from the sun and form cone-shaped shadows.

the light source? What happens to shadows as the opaque object is moved closer to the light source?

2. Notice that the shadow in Fig. C has two sections: a dark, black section in the center; and a lighter, gray section on the outside.

3. SHADOWS IN SPACE

The sun, like the projector in your experiment, gives off light. Any opaque object in space which gets into the path of this light forms a shadow behind it.

Since the earth is in front of the sun at all times it forms a long cone-shaped shadow into space behind it. Just as in your experiment, the center of the shadow is dark and black. This shadow is shaped like a huge ice cream cone. It reaches about 1 390 000 km into space. Also, as in your experiment, there is a wider, gray shadow, which spreads out.

The moon forms a two-section shadow. The inner, darker shadow is about 376 000 km long and is cone-shaped. The outer, gray shadow spreads out into space.

YOU NOW KNOW

- Shadows are formed when an opaque object blocks the path of light.
- Shadows from large sources of light are in two sections; the inner section is darker than the outer section.
- The earth and the moon cause shadows in space when they block the sun's light.

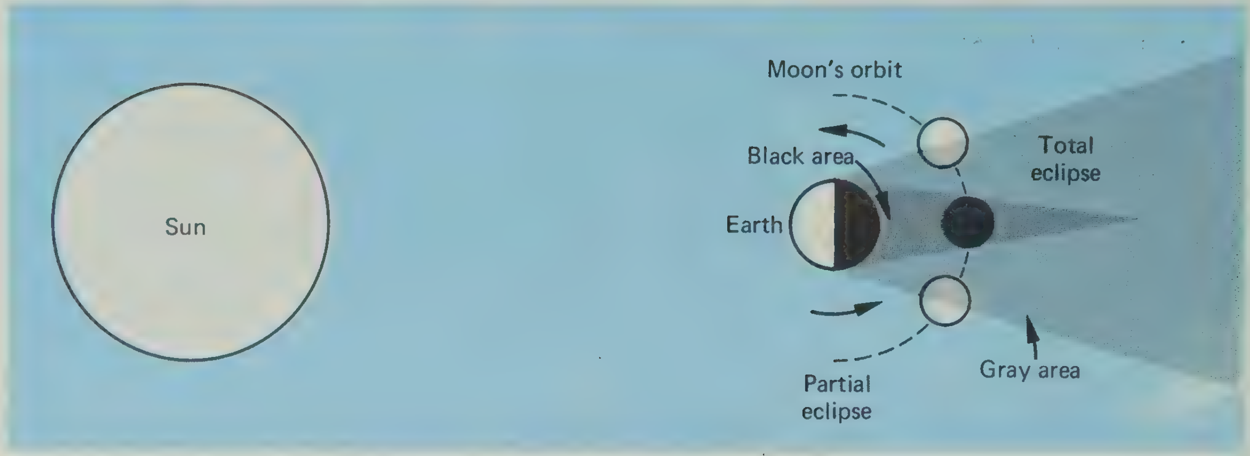


Fig. 110–1

The lunar eclipse is seen across the earth on the side away from the sun.

4. ECLIPSE OF THE MOON

Look back at Fig. 98–1. It shows the phases of the moon. At the full moon phase, the sun, the earth and the moon are in a straight line. The earth is the blocking object. The moon will be in the earth's shadow. If the moon is in the gray area, there will be a *partial lunar eclipse*. If the moon is in the central, dark area, there will be a *total lunar eclipse*. The dark shadow is 9650 km wide at its widest point. The moon's diameter is only 3480 km. Therefore, the view of the whole moon is blocked off from the earth. See Fig. 110–1 and Fig. 110–2.

5. ECLIPSE OF THE SUN

The phases of the moon are shown in Fig. 98–1. At new moon, the moon moves between the sun and the earth. The three bodies again form a straight

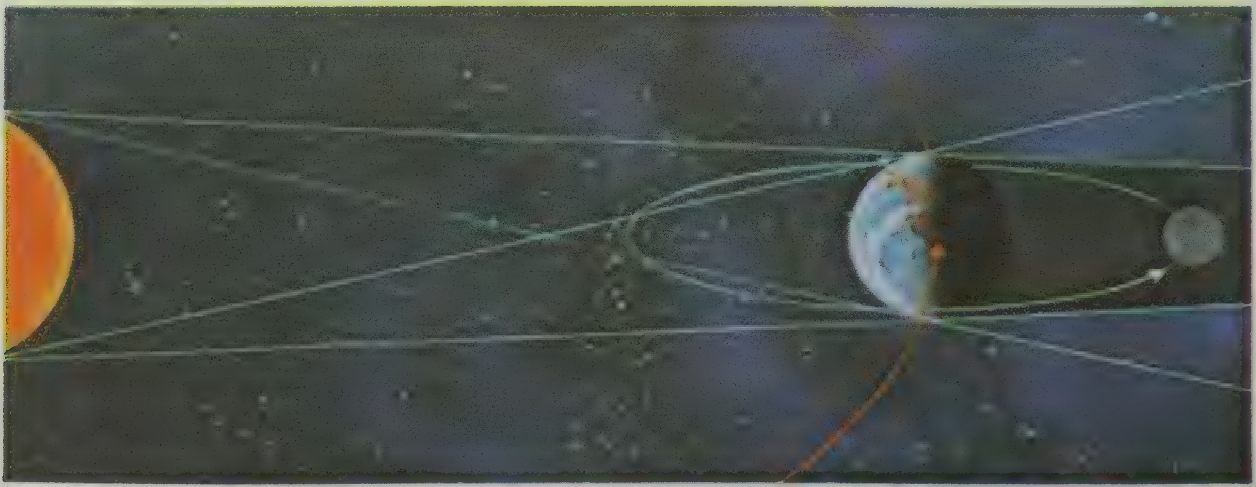


Fig. 110–2

A lunar eclipse is visible to everyone who can see the moon. This occurs on the night side of the earth and only during a full moon.

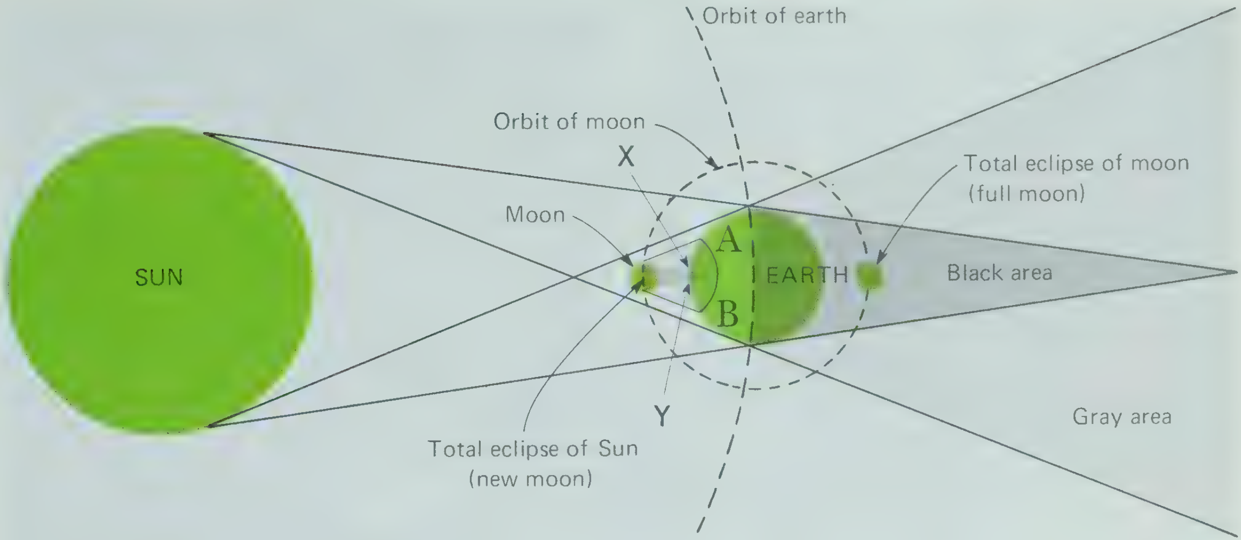


Fig. 111–1

The solar eclipse is seen only in a narrow (X to Y) band across the earth on the side facing the sun.

line. Now the moon casts a shadow on the earth. At the earth, the shadow is very narrow, only about 265 km wide. People in this narrow band (X to Y) see a *total solar eclipse*. People in the area from A to B see a *partial solar eclipse*.

When a total eclipse of the sun comes, it is as if darkness of night has come. In fact, birds have been seen returning to their nests as if it were night. But the total solar eclipse normally lasts about three minutes. It can never last more than 7.5 min. Soon, the moon moves out of the way and daylight returns. See Fig. 111–1 and Fig. 111–2.

6. LET'S DEMONSTRATE ECLIPSES

Would you like to show how eclipses are formed? Attach a tennis ball to a string. Hang it in front of a projector illuminating a globe. The

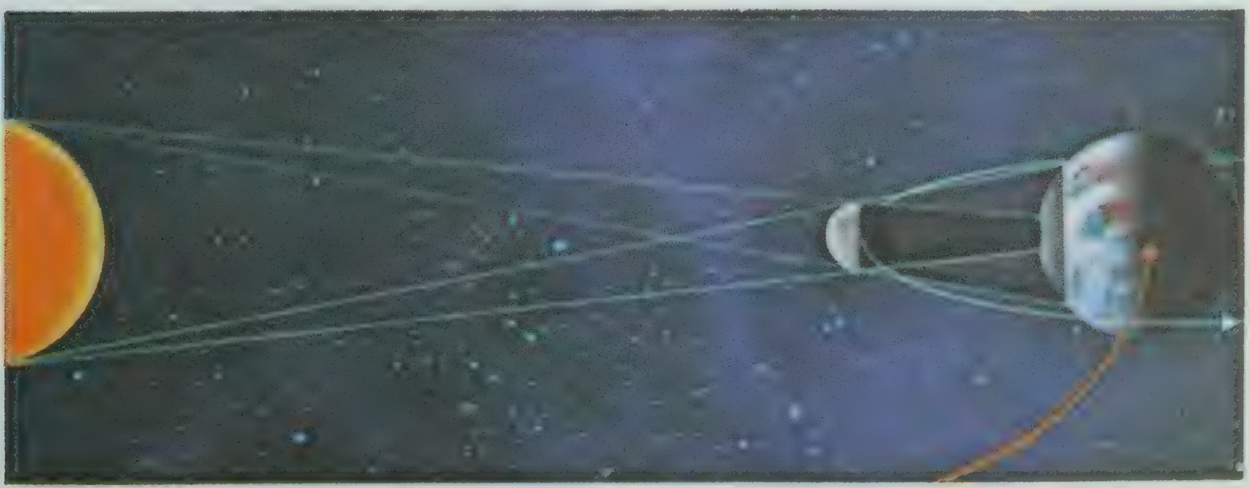


Fig. 111–2

A solar eclipse. People in the dark area on earth see the entire sun blocked out. What do people in the gray area see? Why do people in other parts of the earth see no eclipse at all?

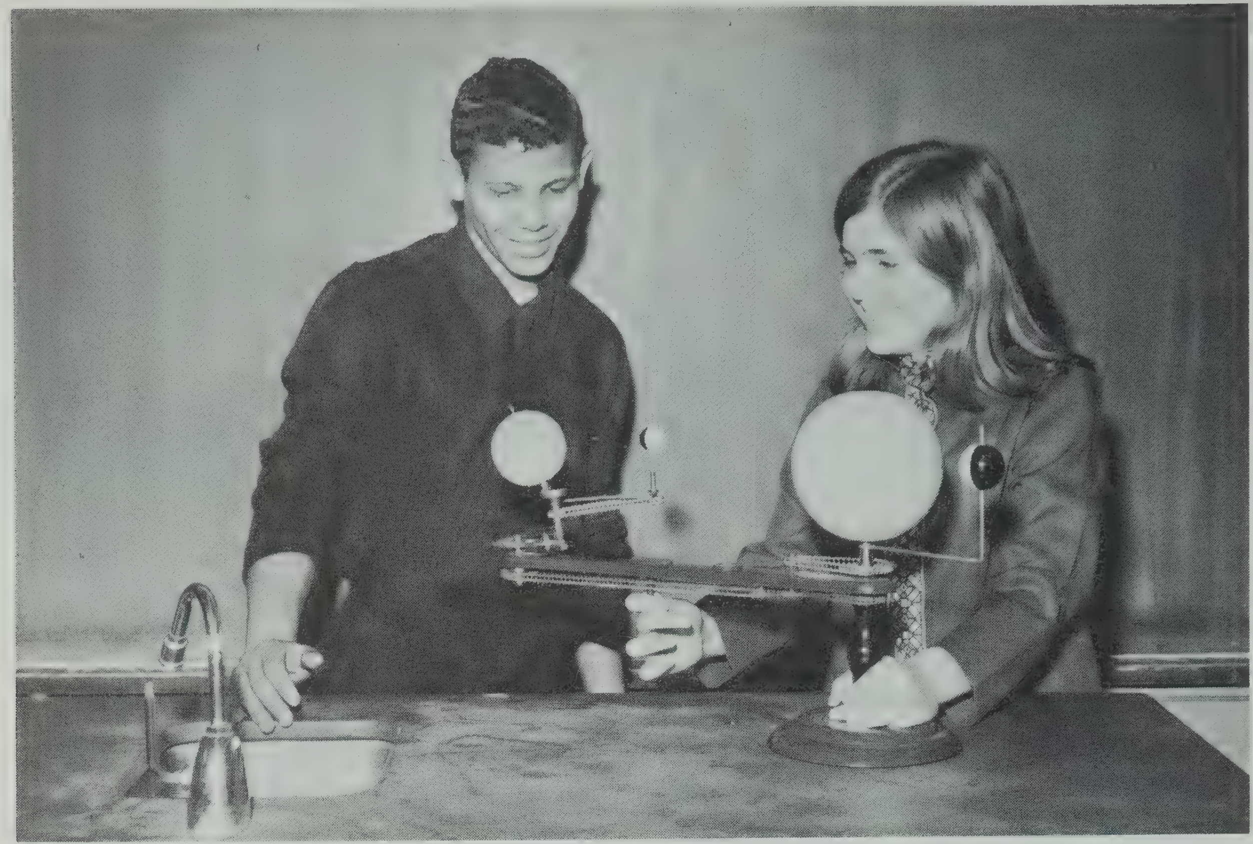


Fig. 112–1

If your school owns a mechanical planetarium, you can see how eclipses happen.

projector represents the sun and the globe represents the earth. By moving the globe, the projector and tennis ball, you can form "eclipses" on the earth. See Fig. 108–1C.

7. WHAT CAN WE LEARN FROM ECLIPSES?

During a lunar eclipse, the earth sometimes appears as a partial shadow on the face of the moon. Our experiments showed us that shadows have the same shape as the objects blocking the light. The shadow of the earth on the moon is part of a circle. This, you remember, was one of the indirect ways to prove that the earth's shape is a sphere.

During a total eclipse of the sun, astronomers can observe and take pic-

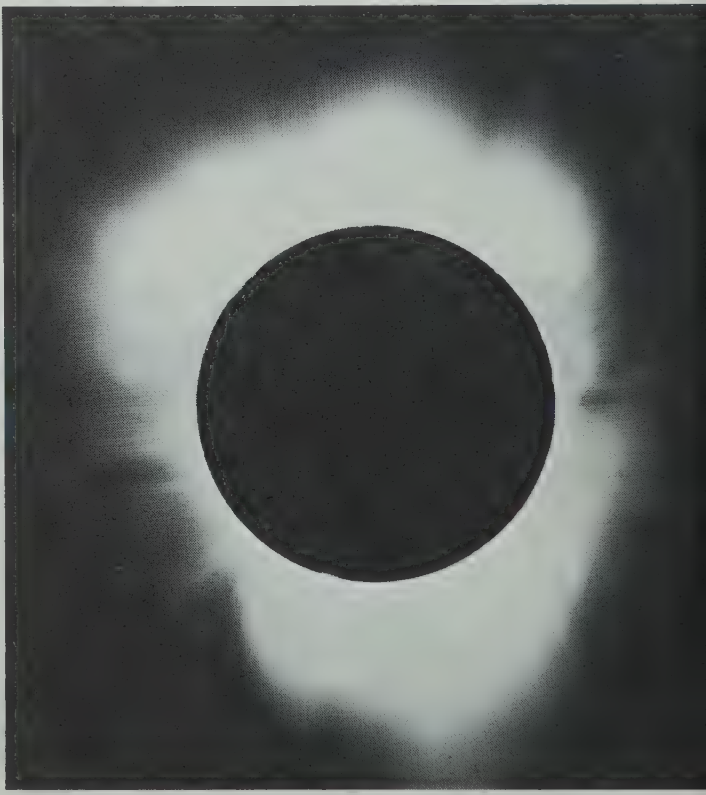


Fig. 112–2

A total eclipse of the sun shows its corona.

tures of the sun's corona and flashes of light around it. The corona appears like a pearly white band around the rim of the moon.

Since solar eclipses take place in very small areas, observations must be done from many parts of the earth. Just before a total solar eclipse, astronomers become very busy. They send expeditions to many parts of the earth. By putting their observations together, they can get a full view of what happens.

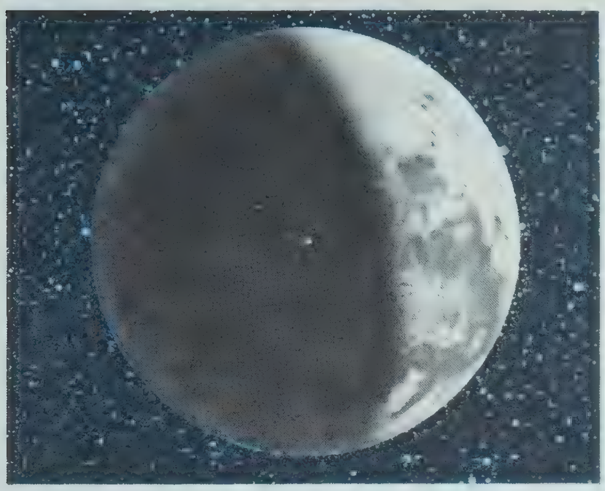


Fig. 113–1

How does this diagram offer proof that the earth is a sphere?

SUMMARY OF ECLIPSES		
	Solar	Lunar
Position of earth Position of moon	Far side of moon Between earth and sun	Between moon and sun Far side of earth
Time for total eclipse	3 to 8 min	About 1.5 h
How often	No more than 50 in 100 years; maximum 5 per year; minimum 2 per year	About once a year; not more than three per year; minimum is zero
Moon's phase	New	Full

UNDERSTANDING WHAT YOU HAVE READ

I. What are the two main ideas in Chapter 15?

1. Shadows may be short or long.
2. Eclipses darken the moon and the earth.
3. We need never be afraid of eclipses.
4. Eclipses are caused by shadows in space.

II. Explanation, Please . . . answer in one or two sentences.

1. What determines the shape of a shadow?
2. What kinds of shadows are formed by the moon in space?
3. During which moon phase can a lunar eclipse be formed?
4. Which lasts longer, a lunar eclipse or a solar eclipse?

III. Knowing What and Why

1. A sphere in space forms a shadow shaped like
   a. a cone.
   b. a corona.
   c. a triangle.
   d. an ellipse.
2. The total eclipse of the moon comes
   a. at full daylight.
   b. at full moon.
   c. only in a leap year.
   d. when we see a new moon.
3. In a solar eclipse,
   a. the earth is between the sun and the moon.
   b. the sun is between the earth and the moon.
   c. the moon is between the sun and the earth.
   d. the moon is not in sight.
4. An astronaut in space viewing a total solar eclipse would see a
   a. shadow on the moon.
   b. shadow on the sun.
   c. shadow on the earth.
   d. corona around the earth.

IV. True or false? Explain your answer.

1. A solar eclipse lasts a shorter time than a lunar eclipse.
2. If the total solar eclipse appears in the U.S., there's no other place it can be seen.
3. Since there is a full moon every month, there is a lunar eclipse every month.
4. During a total eclipse of the sun, we can look at the full sun with our naked eyes.

V. For the Science Whiz

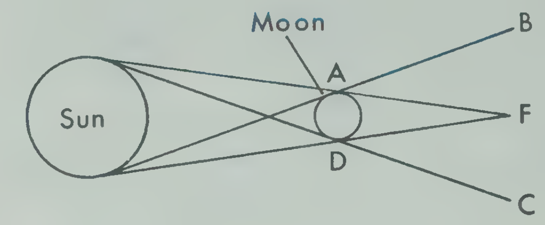


Fig. 114–1

1. Copy the above drawing in your notebook.
2. Shade the area enclosed by A, D and F in pencil.
3. Now shade the area, A, B, F and F, C, D in red pencil. Do not go over the area you shaded before.
4. Write in the letter P in two places where the moon will form a partial eclipse.
5. Write a letter T where the moon will form a total eclipse.

VI. For the Science Reporter

Using an almanac or a good book in astronomy, make a list of the dates when you can see lunar eclipses where you live.

VII. For the Book Lovers

Read the book, *Connecticut Yankee in King Arthur's Court* by Mark Twain. You will discover how a smart character saves his life by predicting an eclipse.

16

TARGET
How do we tell time?

The Time of Day

1. TIME PASSES

Time cannot be touched or weighed. Time is not matter. Time is a *dimension*. We know that "time passes." The passing of time is felt and we speak of less time or more time. Time is money; time is learning; time is resting or playing. Time can go ahead, but never back. And as we said before, "Time and tide wait for no man."

2. CAN YOU TELL THE TIME OF DAY?

You can easily tell that it is "late in the day" or "early in the day." You can tell that it is morning in the a.m. or afternoon in the p.m. You can tell "daybreak" when the sun seems to just peep out over the horizon. It is early morning when the "sun is low in the sky." Time passes and it is noon under a *noonday sun*. The sun is at its highest

Fig. 115–1

How is the time on this clock related to the movement of the earth?

point in the sky for that day. Then the sun begins to "sink" to the west. Time passes and *twilight* comes. Then comes *dusk*, followed by night. If you stayed up all night, once again, the sun would bring daybreak. The cycle of day has been completed.

3. HOW IS TIME OF DAY MEASURED?

The time of day is a cycle or circle. It is the circle which the earth makes as it rotates once on its axis. Time is counted by the motion of the earth which is repeated at a steady rate. Time is therefore a comparison of the rotation of the earth with a given reference point. For most purposes, we use the sun as our reference point. Our day is therefore called the *solar day*. It is counted from one noon to the next noon. Astronomers use the stars as a more precise reference. Such a day is called the SIDEREAL (sy-DEE-ree-ul) day.

4. HOW DO WE MEASURE THE SOLAR DAY?

We start our day at *solar noon*. When the sun forms the shortest shadow *where we live*, that is solar noon.

DO AND DISCOVER

Investigation 8: How can we find solar noon?

What you do:

1. Using a large dinner plate for shape, draw a circle on a sheet of notebook paper. With a protractor (angle measurer) mark off 360° in 10-degree intervals.
2. Bring your paper, an empty spool, a pencil and a magnetic compass outside to a flat, sunny spot. Lay the paper on the ground.
3. Lay the compass on the ground and rotate it until the needle points *north*. Now arrange your paper so that its top is at the north.
4. Place the pencil so it stands in the center of the spool. Then put the spool and pencil in the middle of the circle drawn on the paper.
5. Mark the length of the shadows formed every hour (according to your watch) from 9 a.m. to 3 p.m.

What you see:

The shadows are longer in the morning. They grow shorter towards noon. They grow longer in the afternoon. The shortest shadow usually points north.

What you learn:

1. The shortest shadow is formed at noon, when the sun is at its highest point in the sky. The shortest shadow points north (only when north of 23° north latitude).
2. The solar day is measured from one solar noon to the next solar noon. This is one rotation of the earth on its axis.

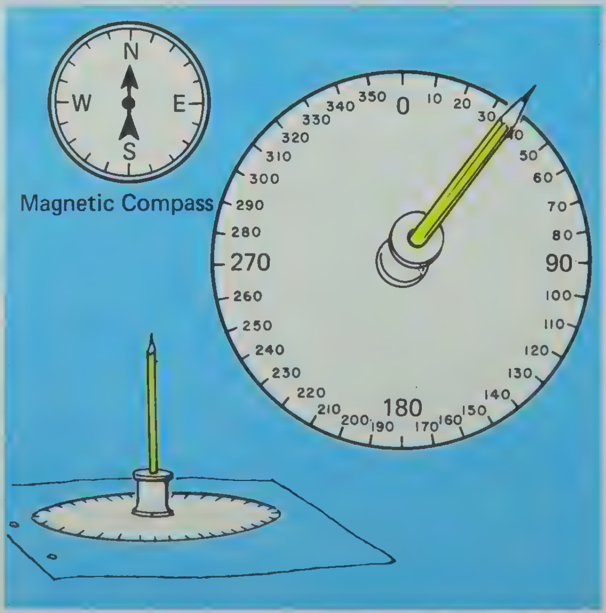


Fig. 116–1

5. INTERVALS OF TIME

You go to school for a "school day." For convenience, however, your school divides your day into *periods*. So, for example, Period 1 is Math; Period 4 is lunch; Period 8 is Science. A period is an amount of time. Another word for a period is an INTERVAL (IN-ter-vul).

The solar day is too long for our daily affairs. A group of ancient people called the BABYLONIANS (bab-i-LO-nee-uns) used the number 12 as the base for their arithmetic. They divided the day into 24 intervals (12 x 2) and called each interval an *hour*. Each hour was divided into *sixty minutes* (12 x 5). Each minute was divided into *sixty seconds* (12 x 5). These intervals have remained in use. They are the same in the English and Metric systems of measurement.

YOU NOW KNOW

- ▶ Time is a continuous dimension.
- ▶ Time of day is measured by rotation of the earth on its axis.
- ▶ Time is based on a solar day from one solar noon to the next.

6. THE TELLERS OF TIME

Watching the sun's shadow is not a perfect way to tell the time of a solar day. But it was the best method known for a long time. The first real timekeeper was the *sundial*. It showed time of day by shadows. But, of course, on cloudy days and at night, the sundial was useless. Besides, the hour markings were not correct as the seasons changed.

New mechanical devices were invented. Water clocks, burning candles, and sandglasses were fairly good

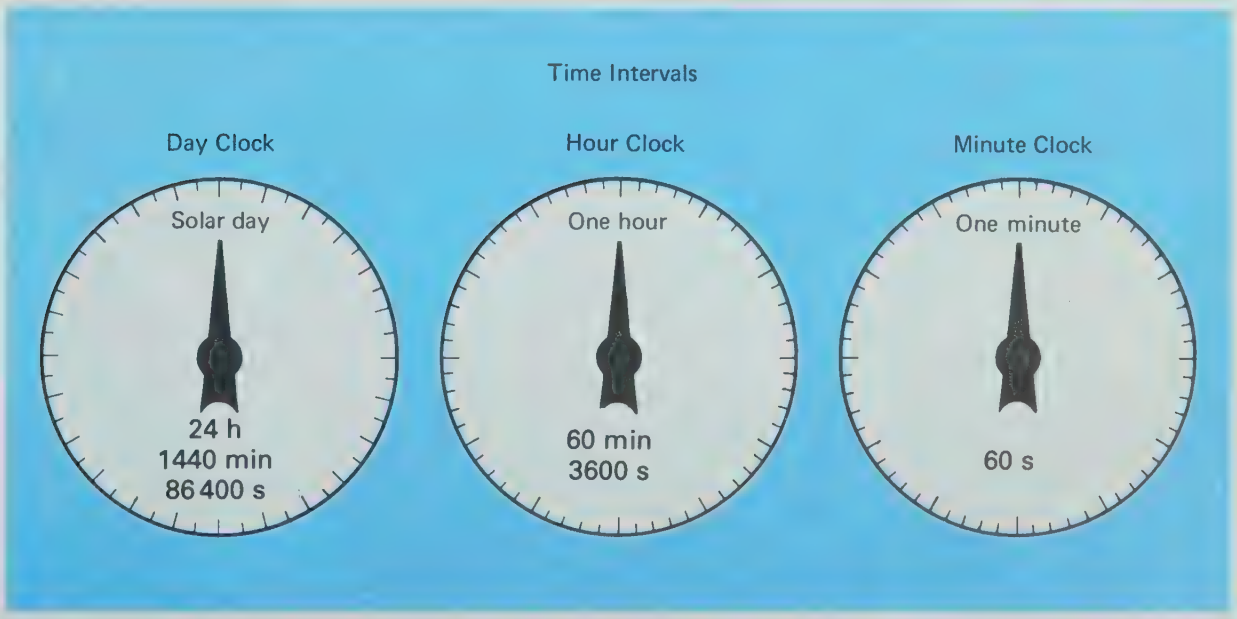


Fig. 117–1

Time intervals have nothing to do with astronomy. Could we have a 10-h day? Could we have an 18-h day?

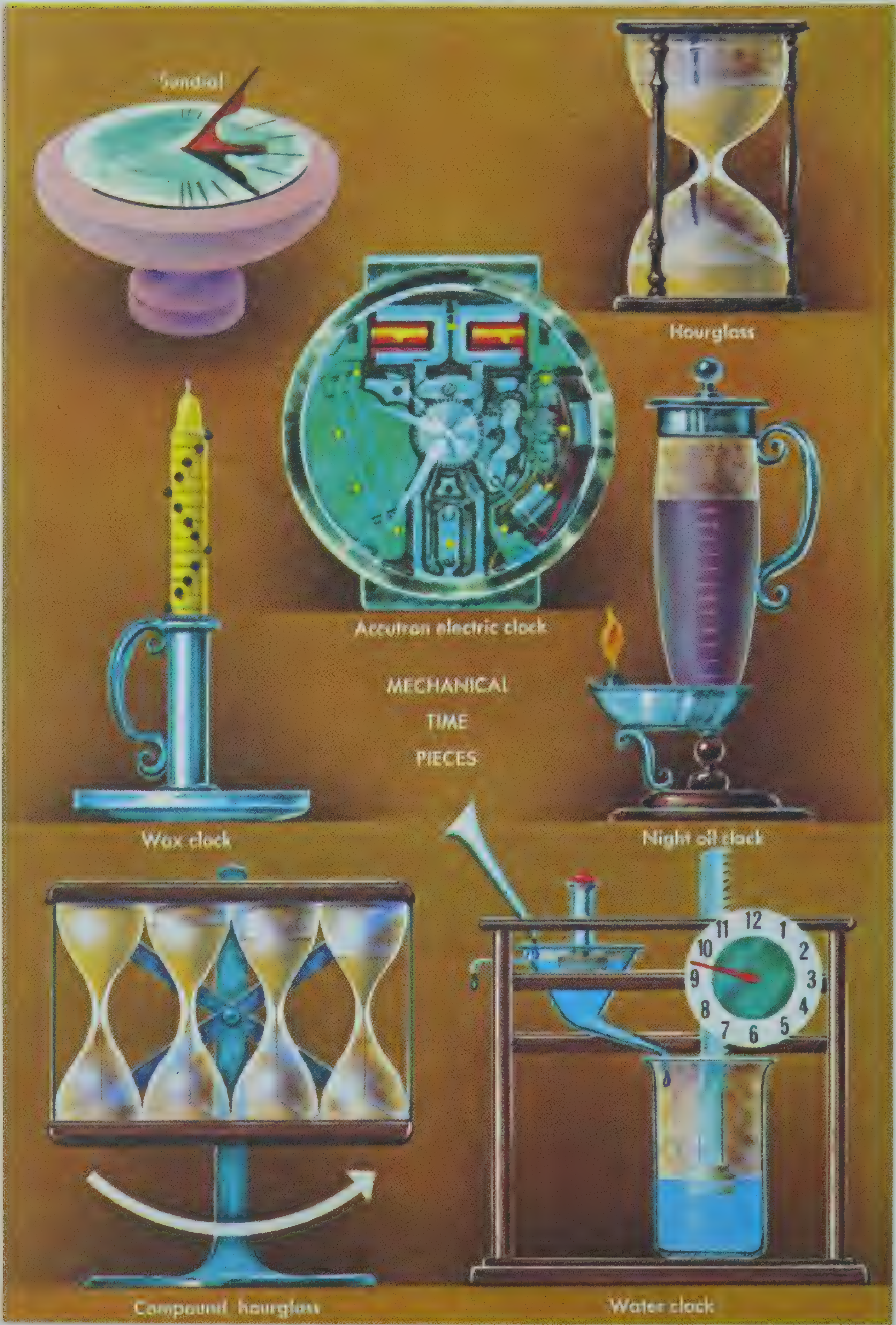

Sundial
Hourglass
Accutron electric clock
Wax clock
MECHANICAL
TIME
PIECES
Night oil clock
Compound hourglass
Water clock
12
1
2
3
4
5
6
7
8
9
10
11

Fig. 118–1

timepieces. Again, someone had to be around to refill the water, turn the sandglass over or light a new candle.

The pendulum clocks were based on Galileo's observations and are remarkably accurate. Watches use gear wheels which are driven by a wound spring. The gears in an electric clock turn at an even speed of 60 times per second. This is the same speed at which the current alternates in the generator. The latest timekeeping invention uses a tuning fork. It contains a tiny battery that operates the tuning fork 360 times a second.

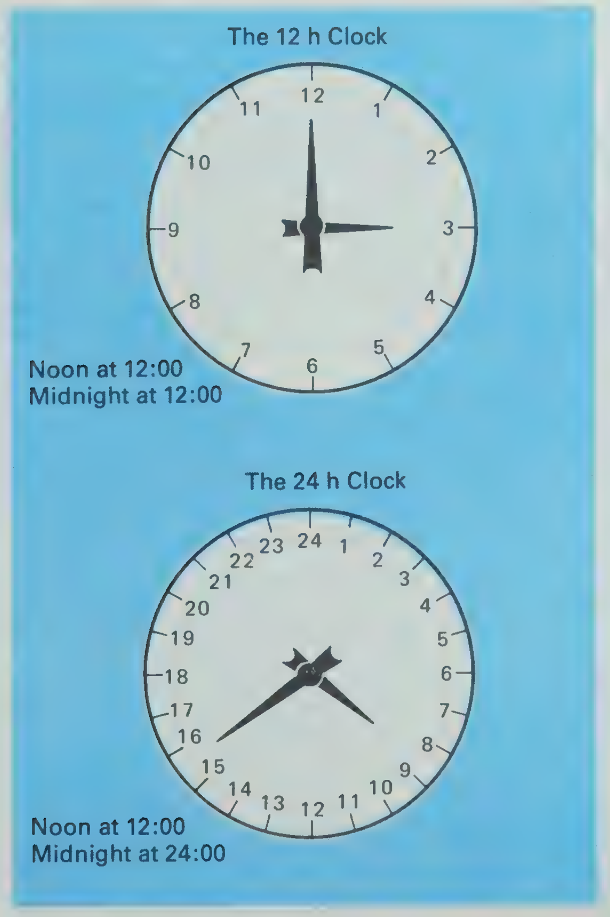


Fig. 119–1

What time is it on the 12 h clock when the 24 h clock reads 15:00? What time is it at 08:14?

7. CLOCK FACES

In most parts of the world, the 24 h solar day is shown on the clock as 12 intervals. The hour hand moves around the face twice in a solar day. From midnight 12:00 to noonday 12:00 is called *a.m.* From noonday 12:00 to midnight 12:00 is called *p.m.* Some airplane and train schedules use the 24 h face.

8. WOULD YOU LIKE TO BE A WATCHMAKER?

Making and repairing watches requires great skill. It is interesting work which pays well. Many cities have vocational or trade schools that teach this skill. There are also private schools that cater to high school graduates. Ask your school counselor for advice.

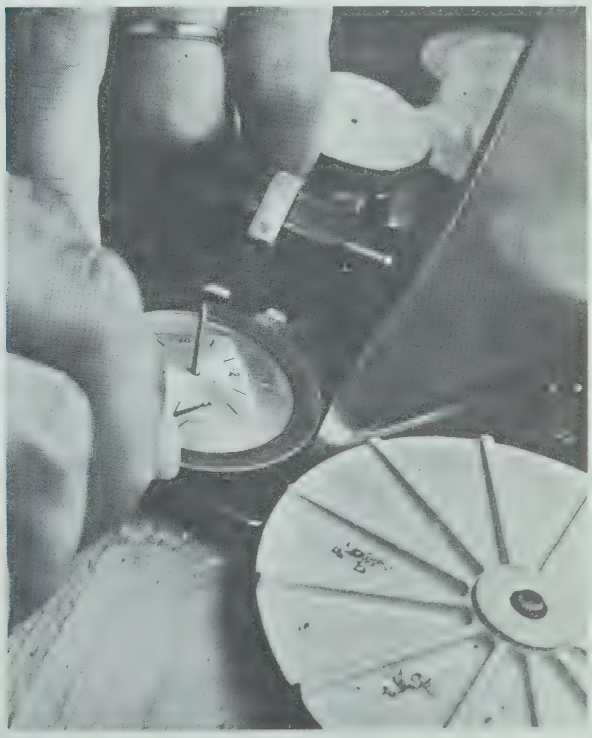


Fig. 119–2

A skilled watchmaker earns good pay and respect. This watchmaker is placing the gold numerals in a dial.

YOU NOW KNOW

- ► The solar day is too long a time interval for conducting our daily affairs.
- ► The solar day is divided into smaller time intervals: hours, minutes and seconds.
- ► Mechanical timekeepers use springs, pendulums, electrical current and tuning forks.

UNDERSTANDING WHAT YOU HAVE READ

I. What are the two main ideas in Chapter 16?

1. Time of day is measured by rotation of the earth on its axis.
2. The sundial, using shadows, is the most accurate timekeeper.
3. Electric clocks work on 60 cycles, like the seconds.
4. A single rotation of the earth is divided into time intervals.

II. In which paragraph do you find the answer?

1. Why are mechanical timekeepers needed?
2. Why is the day based on the number 12?
3. What is solar noon?
4. When are shadows the shortest in the day?

III. Knowing What and Why

1. The solar day runs from solar noon to
   a. lunar noon.
   b. solar noon.
   c. p.m.
   d. the new moon.
2. Usually, the shortest shadow of the day (in our latitude)
   a. points south.
   b. comes only on Dec. 21st each year.
   c. points north.
   d. points in the direction of the moon.
3. The 24 h clock has
   a. twice the number of minutes of a 12 h clock.
   b. as many minutes as you want.
   c. hours only, but no minutes.
   d. the same number of minutes as the 12 h clock.
4. A pendulum clock is made to swing by
   a. the rotation of the earth.
   b. the revolution of the earth.
   c. wound-up springs and gravity.
   d. pushing it.

IV. True or false? Explain your answer.

1. The sun is the only correct reference for measuring time.

2. A clock is not based on astronomy.
3. A 24 h clock does not tell you when it is night.

V. On the ladder of understanding. Choose the word or phrase from inside the parentheses to make each statement correct.

1. Tides are caused mostly by the (moon, sun).
2. Shadows are formed by (translucent, opaque) objects.
3. During a (full moon, new moon), we do not see the moon.
4. The diameter of the moon is about 3 000 km, 12 000 km).
5. The gravity of the moon is (6 times as great, 1/6 as great) as the earth's gravity.

VI. For the Artists

On a large poster board or a paper pie plate, draw a 24 h clock face. Construct movable hands out of cardboard. Fasten them with a paper fastener through the center. Experiment with telling time on the 24 h system.

VII. For the Science Reporter

1. Read about sundials. Report to your class.
2. Ask neighbors, police and mailmen if they know where there are sundials in your community. Try to visit this place to see the sundial. Make sure it is a sunny day.
3. Visit the clock department of a large department store. You will see many kinds of clocks. Write a brief report on what you saw.

PROFILE OF A FAMOUS SCIENTIST

Robert H. Goddard (1882-1945)

Fig. 121–1

Professor Robert H. Goddard (GOD-ard) was an American physicist and inventor who is the father of modern rocket propulsion.

Dr. Goddard built and tested the first rocket which used liquid fuel in 1926. Three years later he sent up a rocket which carried the first scientific "payload": a barometer and a camera. In 1935 he launched a rocket with liquid fuel. It reached a height of 2 290 m at a speed of 1 125 km/h — faster than the speed of sound.

It was not until after his death that Dr. Goddard's genius was recognized. In 1959, the U.S. Congress issued a Gold Medal in his honor. The Goddard Space Flight Center in Maryland is named in his memory.

17

TARGET
Why is time different around the world?

Around the World in Twenty-Four Hours

1. JET PLANES AND BASEBALL GAMES

A Phantom jet plane left New York promptly at 12 noon. It arrived in Los Angeles at five minutes before 12 noon on the same day! The passengers' wrist watches showed five minutes to three. The passengers set their watches to the new time.

The Vancouver Canucks faced off on their home ice at 8:15 p.m. But a mother in Montreal tells her teenagers that it's too late to watch the game on TV. It is already 11:15 p.m.! Does this puzzle you? Perhaps. But it is really easy to understand it. Let's find out.

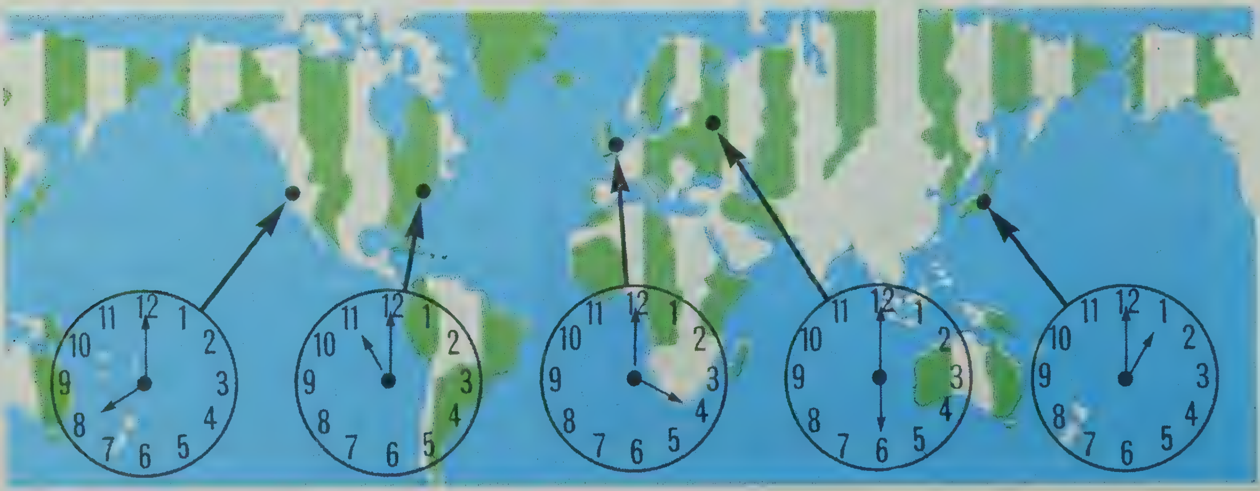


Fig. 122–1

2. SOLAR NOON COMES AT DIFFERENT TIMES

Solar noon, you remember, is at the time when the sun casts its shortest shadow. Take a globe of the earth. Shine a flashlight at any spot. Paste a small strip of masking tape on that spot. Now slowly spin the "earth" from west to east. You can quickly see that the light (solar noon) reaches spots to the west a little after it reaches spots in the east. As you spin the globe, solar noon reaches every spot. After one complete rotation (24 h) the marked spot is back under the light. Solar noon has arrived again.

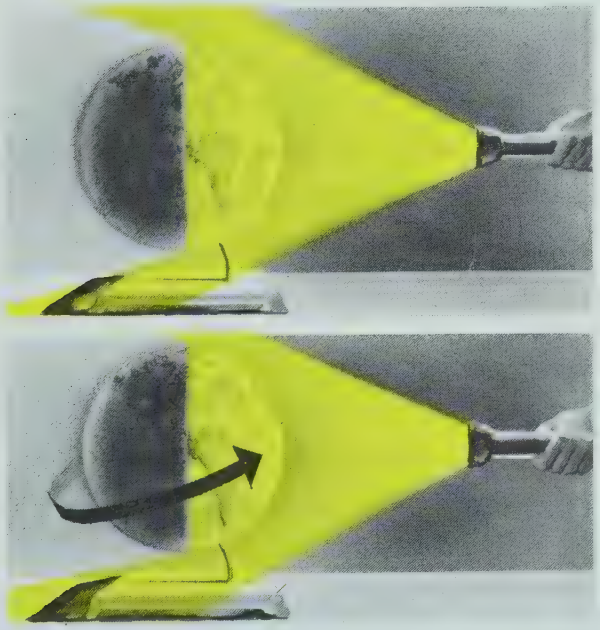


Fig. 123–1

When it is noon on one side of the earth, it is midnight on the opposite side. The west gets solar noon later than the east. Why is it more correct to say, "Chicago came to daylight" than, "Day came to Chicago?"

3. MAKING REFERENCE LINES

Instead of guessing what time it is in various parts of the world, we turn to our maps again. Do you remember your geography?

The map makers divided the globe into imaginary avenues running north and south through the poles. They called these MERIDIANS (muh-RID-ee-unz) or lines of LONGITUDE (LON-ji-tood). The globe was divided into 360°. It was agreed that all references would start from the *prime meridian* (the first meridian line) which is zero degrees (0°).

The map makers also divided the globe with imaginary lines which run east and west. These are called lines of LATITUDE (LAT-i-tood). The equator is the line of latitude which is at zero degrees. Latitude is measured in degrees north and south of the equator.

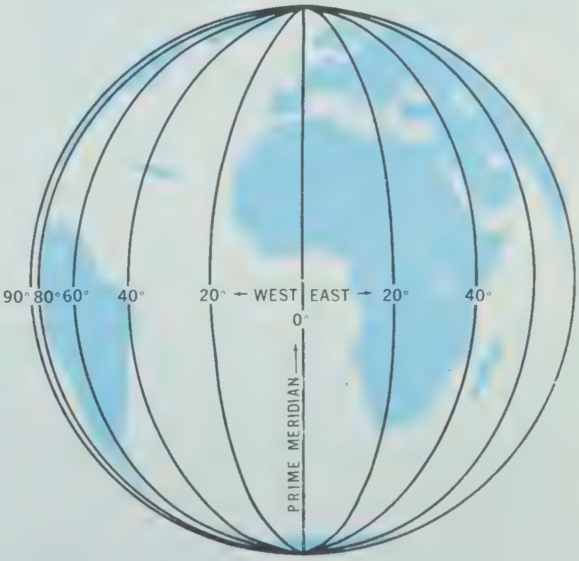


Fig. 123–2

The prime meridian passes through GREENWICH (GREN-itch), England. Locations are degrees *west* of Greenwich, or degrees *east* of Greenwich.

4. TIMES AND LINES

Let us divide the 360° of the globe into equal zones of 15°. 360 ÷ 15 = 24. Does this sound familiar? Of course! It's 24 h. It takes the earth *one hour* to spin the distance from one meridian to the next (15°). If it is solar noon at 0°, then it is not yet noon at 15° west of Greenwich. It is one hour earlier (one hour before noon). At 30° west of Greenwich it is two hours earlier.

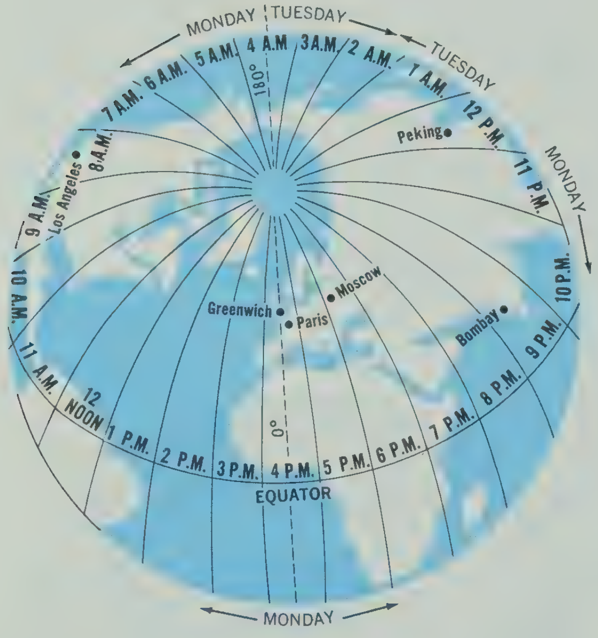


Fig. 124–1

Now let's look east of Greenwich. Refer to Fig. 124–1. It is 4:00 p.m. in Greenwich; at 15° to the east, it is 5:00 p.m. At 30° east, it is 6:00 p.m. The saying below will help you remember this.

> "As you go east, the time does
> increase;
> As you go west, the time does
> grow less."

YOU NOW KNOW

- Time is figured from the prime meridian at 0° in Greenwich.
- Each 15° longitude represents the movement (rotation) of the earth in one hour.
- West of Greenwich, each 15° meridian is *minus* one hour.
- East of Greenwich, each 15° meridian is *plus* one hour.

5. STANDARD TIME AND TIME ZONES

Less than 100 years ago, in this country, everybody kept *local* time based on the solar noon. If you lived right on the 75° West meridian or right on the 90° West meridian, fine! You knew your time with reference to Greenwich. But suppose you lived at 77° W. or 83° W. or 94° W.? Your time would be different by only a few minutes. Under such a plan, the timetables of railroads were all jumbled. Telegraph messages came at the wrong time. You could find that watches all over the country disagreed.

The jumble was solved by introducing *standard time* with *time zones*. At a world conference in 1884, the world was divided into 24 time zones. It was agreed that within a time zone, everybody would set his watch at the same time. The continental United States has four time zones. Canada has seven time zones. Each one of these zones differs from the other by one hour, except Newfoundland Standard Time which differs by only 30 min.

Now you can see why a baseball game played in Los Angeles at 1:00 p.m. (Pacific Standard Time), can be

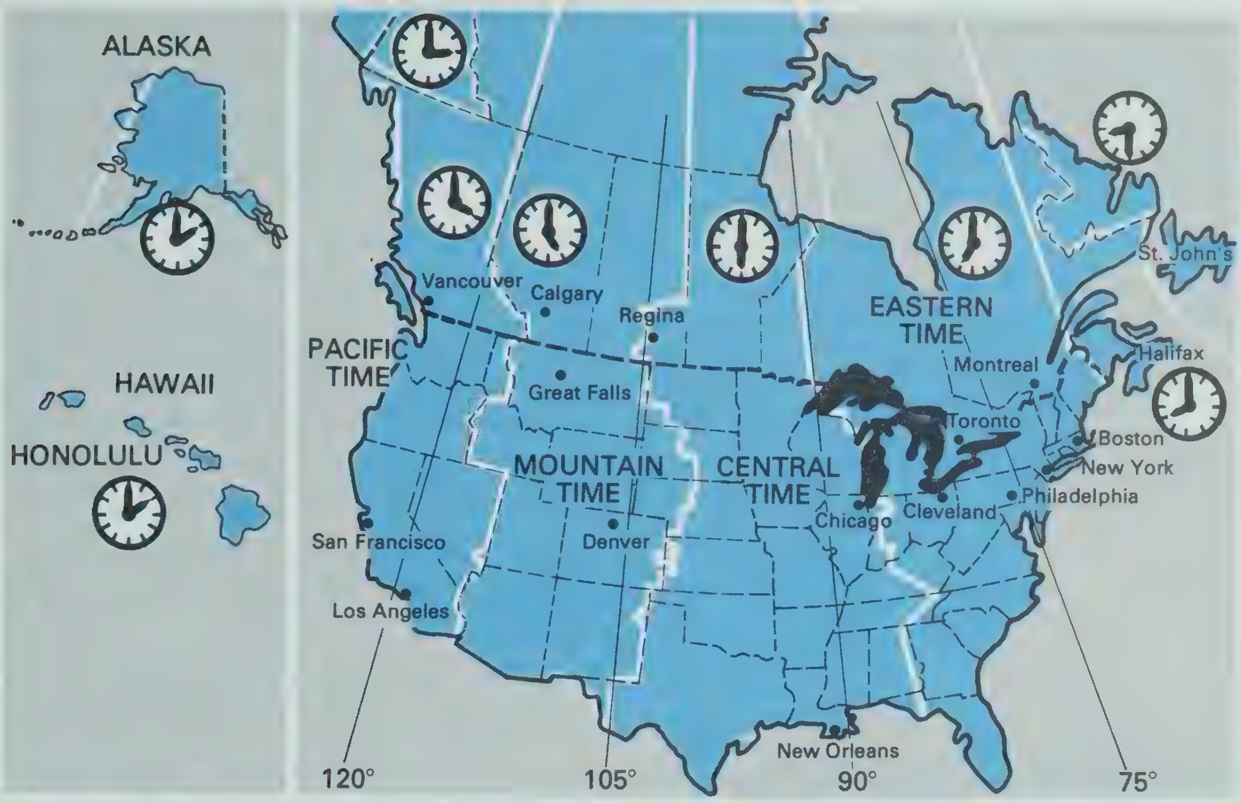


Fig. 125–1

Can you explain why the time zone boundary lines are not straight lines? Notice that these boundary lines are not the same as the meridian lines. Why?

seen on TV in Toronto at 4:00 p.m. (Eastern Standard Time).

6. TWO BIRTHDAYS FOR ONE

How would you like to celebrate your birthday *twice* a year? Of course this sounds silly. But it *can* be done!

Look back at Fig. 124–1. Let your finger travel from Greenwich, eastward. If you go for twelve hours, it is four o'clock in the morning on Tuesday! And you are on the 180° meridian. Now start again from Greenwich.

WHAT TIME IS IT AT GREENWICH STANDARD TIME?

Newfoundland Standard Time	(NST)	add $3^{1}/_{2}$ h to get Greenwich time
Atlantic Standard Time	(AST)	add 4 h to get Greenwich time
Eastern Standard Time	(EST)	add 5 h to get Greenwich time
Central Standard Time	(CST)	add 6 h to get Greenwich time
Mountain Standard Time	(MST)	add 7 h to get Greenwich time
Pacific Standard Time	(PST)	add 8 h to get Greenwich time
Yukon Standard Time	(YST)	add 9 h to get Greenwich time
Alaskan Standard Time	(AST)	add 10 h to get Greenwich time
Hawaiian Standard Time	(HST)	add 10 h to get Greenwich time

east side. This line has been set up to keep the days straight. It is called the *International Date Line*.

If you cross the line from east to west, you gain a day. So if you want two birthday celebrations, it's easy! Celebrate your birthday in Japan. Fly eastward across the International Date Line. It is one day earlier in California. Celebrate your birthday a second time.

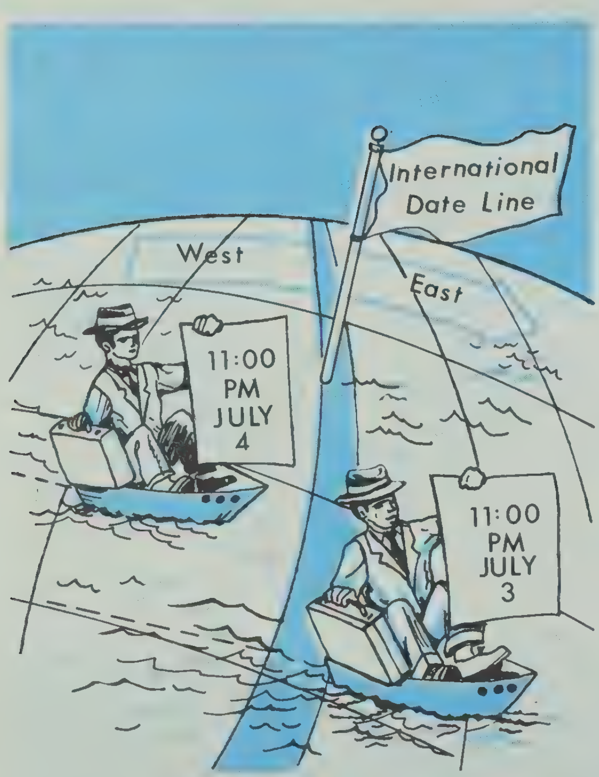


Fig. 126–1

Is the man at the left going east or west? Explain your answer.

7. DAYLIGHT SAVINGS TIME

You have heard of Benjamin Franklin as the man with the kite experiment. He was also famous for his belief in saving money. But Ben Franklin also invented a way to "save time." He called this idea *Daylight Savings Time*. However, it was not used in the U.S. and Canada until World War I. Now it is fairly common. In the spring of each year, many (but not all) states and provinces have the people move their clocks *ahead* one hour. If it normally gets dark at 7:30 p.m. in a certain area, it will get dark at 8:30 p.m. Daylight Savings Time lasts into the fall. Days are longer in the summer. Therefore, by the time most of us get up in the morning, it is light anyway.

In 1967, the U.S. Congress passed a law which sets Daylight Savings Time (DST) to begin at 2:00 a.m. on the last Sunday in April. It ends on the last Sunday in October. However, Daylight Savings Time is still not in effect in many states.

In Canada, during World War II, Daylight Savings Time was in effect throughout the country. Since that time it has become a matter of provincial law.

YOU NOW KNOW

- Standard time is measured with reference to Greenwich.
- Each 15° zone of longitude stands for 1 h of time.
- Time zones are agreed areas in which every community keeps the same time.
- Canada has seven time zones; the continental United States has four.
- The International Date Line is the 180° meridian. It marks the beginning of one day and the end of another.

UNDERSTANDING WHAT YOU HAVE READ

I. What are the two main ideas in Chapter 17?

1. Time never stands still.
2. Daylight Savings Time is really a fraud.
3. Rotation of the earth brings solar noon at different times to different places.
4. Time is different in different parts of the earth.

II. In which paragraph do you find the answer?

1. Does a city west of Greenwich get noon later than Greenwich?
2. How many meridian lines are there on the globe?
3. Why does North America have so many time zones?
4. What do travelers do to their calendars when they cross the International Date Line going east?

III. Knowing What and Why

1. Daylight Savings Time
    a. changes the rate of rotation of the earth.
    b. changes the speed of the clock's mechanism.
    c. adds an hour to the daylight period.
    d. provides a 23-h day.
2. The prime meridian was placed where it is
    a. by agreement of the nations.
    b. because Greenwich is so far east.
    c. because it is near Big Ben.
    d. because it always points to the North Star.
3. New York is 5 h earlier than Greenwich. Therefore,
    a. New York is at 75° longitude west (5 x 15°).
    b. New York is 5 h east of Greenwich.
    c. New York is at 15° longitude (5 x 3°).
    d. New York uses American time.
4. Time zone lines are
    a. exactly like the lines of longitude.
    b. exactly like the lines of latitude.
    c. irregular boundaries, running north and south.
    d. irregular boundaries, running east and west.

IV. Match the words in Column A with those in Column B.

A	B
1. Greenwich	a. 15° longitude
2. California	b. 180° longitude
3. Pacific Ocean	c. Eastern Daylight Time
4. Solar noon	d. west to east
5. rotation of earth	e. Pacific Standard Time
6. Toronto	f. shortest shadow
	g. zero degrees longitude
	h. International Date Line

V. Understanding the Investigation

Study the investigation in Paragraph 2.

1. If you rotated the "earth" in the opposite direction, would there be a difference in results? Explain.
2. Why did we mark the globe with masking tape?
3. If you had no flashlight, could you use a lamp? Explain.

VI. Understanding Science News.

Study the diagram. Read the article. Then answer the questions.

Flood Tides

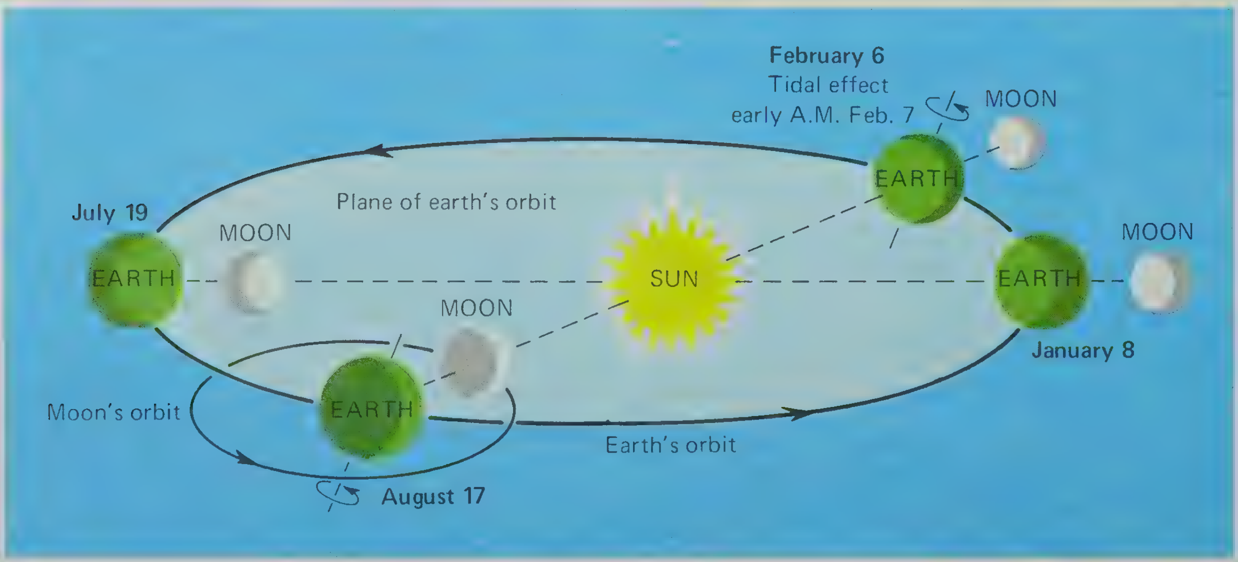
Celestial events due in the early 1990s may have a costly effect on many residents living in low-lying coastal areas around the world. Because of an unusual set of astronomical coincidences involving the positions of the earth, moon and sun, ocean tides at that time will rise to great heights.

"Should a sustained onshore wind occur during these high waters," says NOAA (U.S. National Oceanographic and Atmospheric Administration), "a destructive water level could result, causing widespread coastal damage." NOAA points to the storms of March 6 and 7, 1962, as an example of what could occur. Unfavorable winds between 40 and 70 knots developed on the same days and created gale-force winds and floods that claimed 40 lives and wrought some $500 million damage from the Outer Banks of North Carolina to Long Island, N.Y. This particular storm then swung out to sea, leaving little damage along the Canadian coast.

The same alignment of earth, moon and sun occurred in 1974. Did anything unusual happen as a result? Since the years of perigee-syzygy tides occur in pairs, 1975 was another year of abnormal water levels. These tides will not occur again till the early 1990s.

As might be expected, every precaution is being taken to forestall possible disaster in the future. With the advanced forecasting available from today's orbiting weather satellites, cities along the coast of North America will not be caught off guard during periods of high ocean tides.

Alignment of forces: The four dates in 1974 when flooding in coastal areas was greatest.



1. Why will the tides in the 1990s be much higher than usual?
2. When was the last time this kind of "line-up" took place?
3. In the dictionary, look up the words *perigee* (PER-uh-jee) and *syzygy* (SIZ-uh-jee). What do these words mean?
4. Why may we expect less damage now than in the past?

18

TARGET
How do we keep track of days, months and years?

The Time of the Year

1. LOOKING BACK . . .

Rotation of the earth is used to count days. Are there other movements in space by which we can keep track of time? You know that the moon has regular motions. So people began to count *moonths*, which became *months*. The earth revolves and rotates around the sun. Careful counting showed long ago that these rotations happen about 365 times until the earth is back in its first position. And so there is the *year*. When days, months and years are put together to keep account of our time, we have a CALENDAR (KAL-en-dur).

2. TWELVE TIMES A YEAR

From new moon to new moon, ancient people counted a moonth (month; 12 moonths a year). But at the end of the year, something was wrong. The twelve months were 11 d short of the year. No wonder! 12 × 29.5 d = 354 d. Ancient Chinese and Hebrews had to adjust their calendars every few years by adding a thirteenth month. It became obvious that a better calendar is one based on the sun. It takes about 365 d for one revolution of the earth around the sun. This is more precise and more exact.

DAYS OF THE WEEK	
Day	*Named After*
Sunday	The sun's day
Monday	The moon's day
Tuesday	Tiw (translation of Mars)
Wednesday	Woden (chief English god)
Thursday	Thor (god of thunder)
Friday	Frigg (Woden's wife)
Saturday	Saturn's day

3. EARLY CALENDARS

One of the earliest calendars was the Roman calendar. Julius Caesar, the Emperor of Rome, helped develop a new calendar. It was called the *Julian Calendar*. The Julian Calendar was a sun calendar which had 365.25 d, the precise number of rotations of the earth. The months were all numbers from one to ten (I to X). Later, more months were added and given new names.

MONTHS OF THE YEAR	
Month	*Named After*
January	Janus— Roman god of beginning
February	Februa— Roman feast of purity
March	Mars— Roman god of war
April	Aperio— far away
May	Maia— Roman goddess of reproduction
June	Junius— a Roman family
July	Julius— Caesar's first name
August	Augustus— Emperor of Rome
September	Septem— the original 7th month
October	Octo— the original 8th month
November	Novem the original 9th month
December	Decem— the original 10th month

4. POPE GREGORY CHANGES THE CALENDAR

The trouble with the Julian Calendar was that it kept slipping back. By the year 1582, spring came on March 11th instead of March 21. Pope Gregory appointed astronomers to work out a new calendar. It is the one we use today. It is called the GREGORIAN (greh-GOR-ee-un) Calendar. It adds up to 365 d a year. Every fourth year is *leap year*. Then the month of February has 29 d ($4 \times {}^{1}/_{4} = 1$ full day). A

GREGORIAN CALENDAR

4 months × 30 d = 120 d
(September, April, June, November)

7 months × 31 d = 217 d
(all the rest except February)

1 month × 28 d = 28 d
(February, in regular years)
120 + 217 + 28 = 365 d

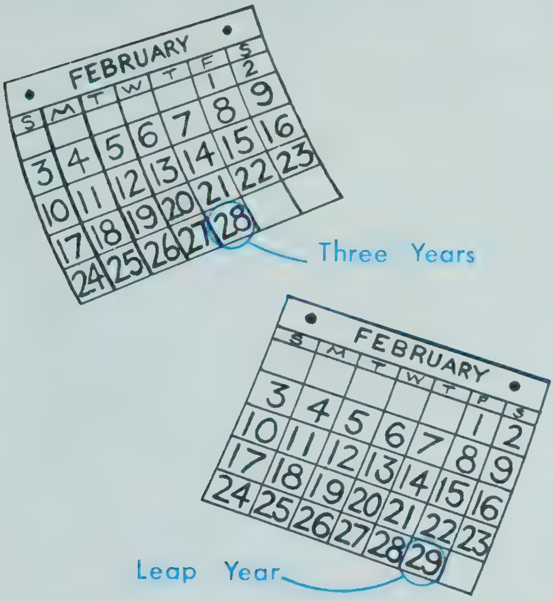


Fig. 131–1

The leap year adds a day in February every fourth year. In the Gilbert and Sullivan Operetta, *Pirates of Penzance,* one pirate is born on Feb. 29. At 20, he claims to be only 5 years old!

leap year is one which you can divide evenly by 4. The year 1976 was a leap year (1976 ÷ 4 = 494). However, leap years are omitted in the century years which are not divisible by 400. The year 2100 A.D. will *not* be a leap year. The year 2000 A.D. will be a leap year.

MANY-YEAR PERIODS	
Decade:	10 years
Jubilee:	50 years
Century:	100 years
Millennium:	1000 years
Geologic eras:	Millions of years

YOU NOW KNOW

- A calendar keeps track of days, months and years.
- Our present calendar is the Gregorian Calendar.
- Our calendar has 365 d which make up twelve months.

5. WHAT ARE THE SEASONS?

Seasons are periods of time. There are four such periods and they come regularly. They come regularly because our earth revolves around the sun regularly in its orbit. The four seasons are spring, summer, autumn (fall) and winter. Careful observations have shown that seasons mean two things. They mean a change in temperature and a change in the length of day and night. Let us read on to see what causes the seasons.

Seasons
1. Length of day and night
2. Temperature

6. MORE REFERENCE LINES

We saw that reference lines on a map which show east and west are the lines of longitude. To show positions of north and south, we use imaginary lines running around the earth. The equator is around the middle. The Tropic of Cancer is 23.5° north of the equator. The Tropic of Capricorn is 23.5° south of the equator. The Arctic Circle, near the North Pole, is 66.5°

north of the equator. The Antarctic Circle, near the South Pole, is 66.5° south of the equator. These are the *lines of latitude*.

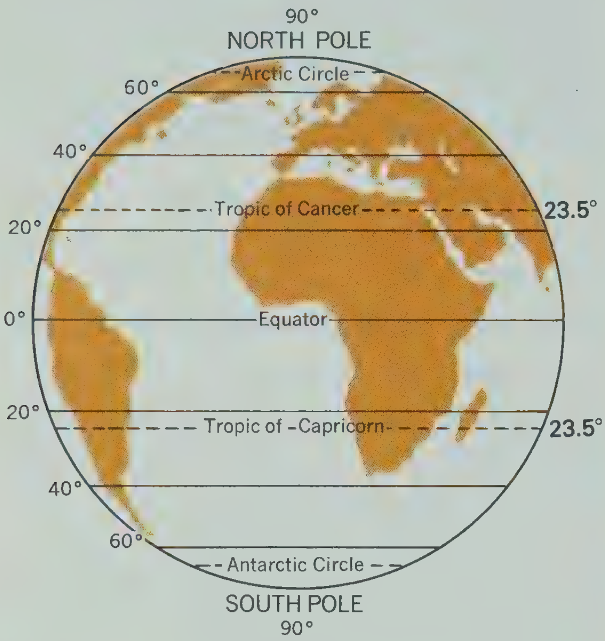


Fig. 132–1

Lines of latitude are drawn around the earth parallel to one another and help us locate places north and south of the equator.

7. DIRECT RAYS AND SLANTING RAYS

The amount of heat that reaches the earth from the sun is not the same all over. If you look at Fig. 133–1, you will see that the sun's rays at the equator are direct. As you go from the equator, north or south, towards the poles, the rays are slanting. How does this change the amount of heat that is received by the different places on earth?

DO AND DISCOVER

Investigation 9: How do slanting rays affect heat?

What you do:

1. Set up the two experiments as shown in Fig. 132–2.

What you see:

In Fig. 132–2A, the area of light is larger with slanting rays than with direct rays. In Fig. 132–2B, the temperature is higher with the direct rays (left) than with the more slanted (right).

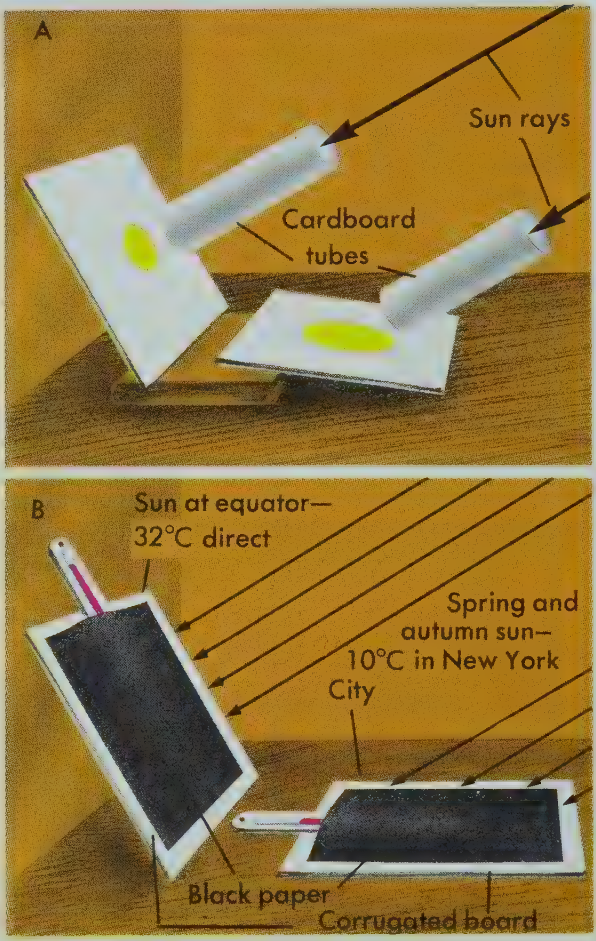

A
Sun rays
Cardboard tubes
B
Sun at equator—32°C direct
Spring and autumn sun—10°C in New York City
Black paper
Corrugated board

Fig. 132–2

What you learn:

Light falling at a slant covers a wide area. Therefore, its heat is spread out. When light is spread out on an area, it gives less heat than direct rays on a smaller area.

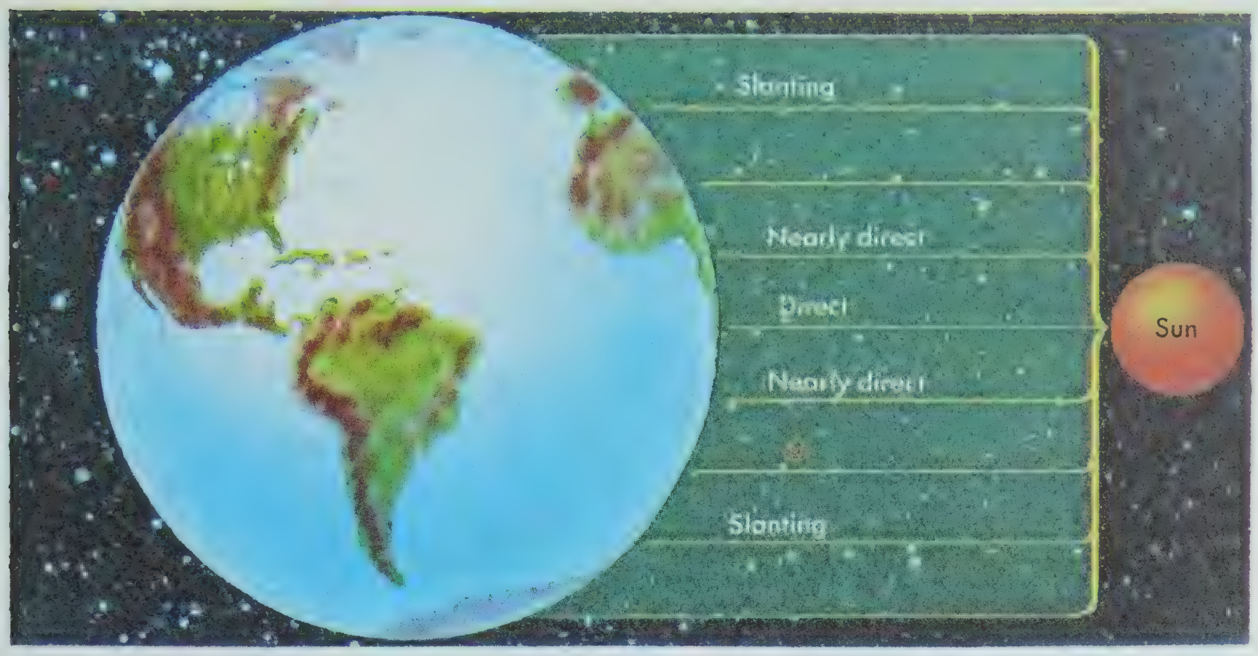


Fig. 133–1

What is the date when this takes place? On what line of latitude are the direct rays of the sun?

8. THE EARTH TILTS ON ITS AXIS

Look at Fig. 134–1. You can see that the earth tilts on its axis. It tilts 23.5° away from the vertical (straight up and down) position. The axis points at the North Star no matter where the earth is in its orbit. When the earth's axis tilts toward the sun, the northern hemisphere gets more daylight. The part of the earth that tilts away gets less daylight. The part of the earth that spends more hours in the sun will be warmer. Your experiment showed you that direct, parallel rays of the sun produce more heat than slanted rays.

Fig. 133–2

9. LET'S FOLLOW THE SEASONS

Examine Fig. 134–1 which shows the positions of the earth in its orbit. Set up an electric light without a shade in the middle of a large table. Use a small globe and revolve the globe to each position. Now examine Fig. 135–1. This shows the earth in each position in a "close-up."

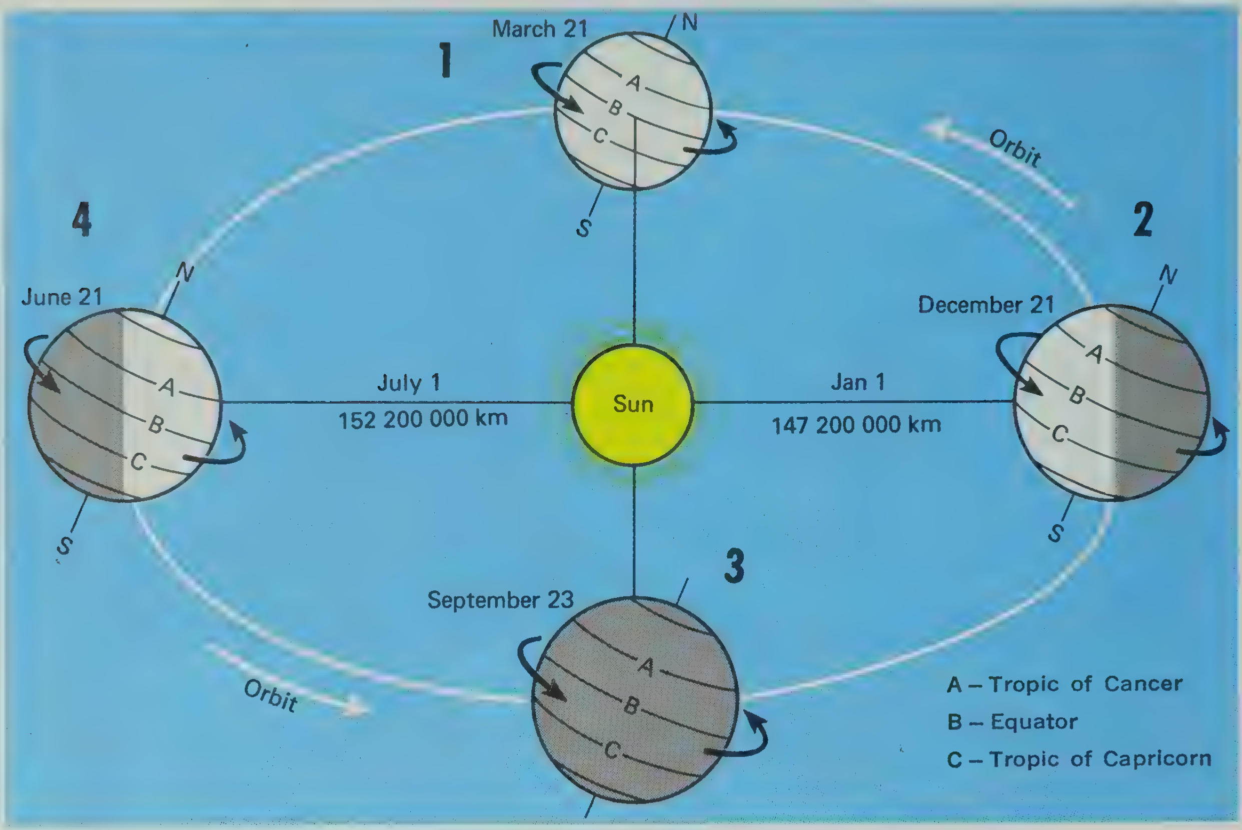


Fig. 134–1

The earth's axis always points toward the North Star. Even though the earth is closest to the sun in the wintertime, it is the coldest season in the Northern Hemisphere.

10. LIFE AND SEASONS

Seasonal change affects people and the environment. Most plants and animals show change in growth and behavior as the seasons change.

Spring means warmth. Plants and trees show great spurts of growth. Buds on trees begin to swell and open to form new leaves. Sunflowers bloom in the spring; other flowers bloom in the summer or fall. As the fall season starts, many trees drop their leaves and prepare for winter.

Many animals begin their breeding season in the spring. The young grow rapidly during warm weather. As fall and winter approach, some animals build winter nests or burrows in the ground. Some animals even "go to sleep" for the winter. We say they HIBERNATE (HY-bur-nayt). The bear is a good example.

We, too, are very much affected by seasons. For example we change our clothing as the weather changes. Homes are heated in the winter, or air-cooled in the summer. Many people even change their diets. In summer they switch to "lighter" foods such as more vegetables, less meat and less fat.

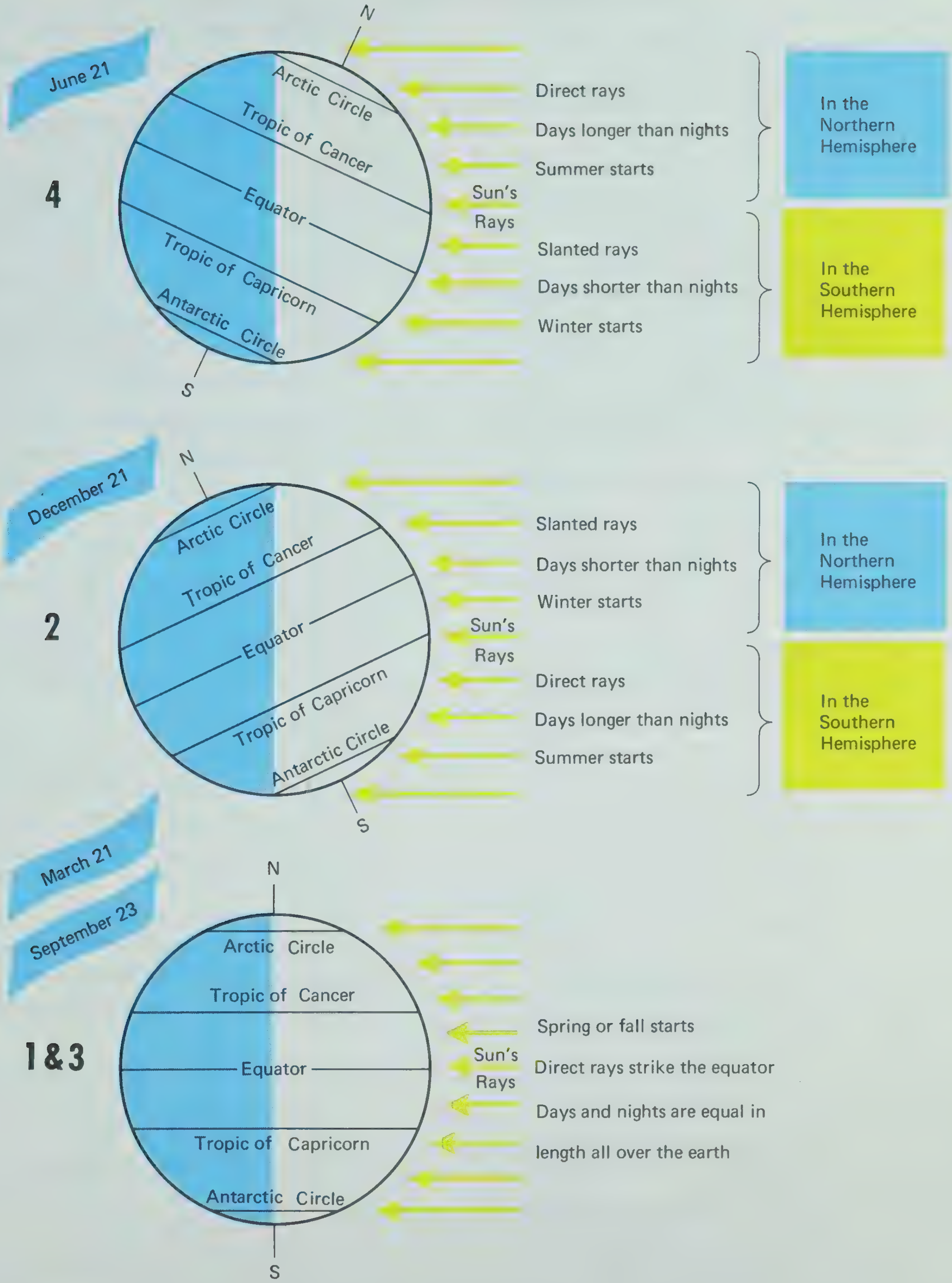

June 21
4
N
Arctic Circle
Tropic of Cancer
Equator
Tropic of Capricorn
Antarctic Circle
S
Sun's
Rays
Direct rays
Days longer than nights
Summer starts
In the
Northern
Hemisphere
Slanted rays
Days shorter than nights
Winter starts
In the
Southern
Hemisphere
December 21
2
N
Arctic Circle
Tropic of Cancer
Equator
Tropic of Capricorn
Antarctic Circle
S
Sun's
Rays
Slanted rays
Days shorter than nights
Winter starts
In the
Northern
Hemisphere
Direct rays
Days longer than nights
Summer starts
In the
Southern
Hemisphere
March 21
September 23
1&3
N
Arctic Circle
Tropic of Cancer
Equator
Tropic of Capricorn
Antarctic Circle
S
Sun's
Rays
Spring or fall starts
Direct rays strike the equator
Days and nights are equal in
length all over the earth

Fig. 135–1

UNDERSTANDING WHAT YOU HAVE READ

I. What are the two main ideas in Chapter 18?

1. Calendars can be based on moon or sun motions.
2. Seasons are caused by the tilted earth in its orbit around the sun.
3. Slanted rays of the sun gave rise to the Gregorian Calendar.
4. Calendars must be adjusted in a leap year.

II. Explanation, Please . . . answer in one or two sentences.

1. What two conditions change with seasons?
2. Which rays produce more heat, direct or slanted?
3. When is it summer in Brazil?
4. What is the Gregorian Calendar?

III. Knowing What and Why

1. The farthest point reached by direct rays in the northern hemisphere is the
    - a. equator.
    - b. Tropic of Cancer.
    - c. prime meridian.
    - d. Arctic Circle.
2. The lunar calendar is a poor one because
    - a. there are extra days in the year.
    - b. it has extra hours each month.
    - c. only ancient people used it.
    - d. Pope Gregory outlawed it.
3. As the earth revolves in its orbit around the sun,
    - a. its North Pole points to the North Star.
    - b. the equator changes position.
    - c. the year gets longer.
    - d. more slanted rays touch the north pole.
4. We would always have exactly 12 h of daylight and 12 h of darkness if
    - a. the earth revolved faster.
    - b. rotation were equal to revolution.
    - c. the earth were not tilted on its axis.
    - d. moonshine were not so weak.

IV. Understanding the Experiments and Diagrams

Study the experiment and diagram (Fig. 132–2) in Paragraph 7.

1. What is the purpose of the black paper in Diagram B?
2. What does Diagram A prove?
3. On what date of the year does the equator have rays like those shown in Diagram B?

Study Fig. 135–1.

1. In which diagram will the North Pole have 24 h of daylight?
2. In which diagram does the South Pole have 24 h of daylight?

V. Brain Teasers

1. Will 1997 be a leap year? Prove it.
2. Does the period from January 1 to June 30 have exactly $^1/_2$ of the number of days in the year? Prove it.
3. On how many days of the year does the latitude where you live have 12 h of daylight? Explain.
4. Where is the "Land of the Midnight Sun"? Explain.
5. Research shows George Washington was born on February 11th yet his birthday is celebrated on February 22 in the U.S. Explain why.

VI. For the Science Reporter

Use a good dictionary.

1. Look up a.m. and p.m. Explain what they mean.
2. What does A.D. mean? What does B.C. mean?
3. What does vernal equinox mean?
4. What does summer solstice mean?

Glossary: What Does It Mean?

anorthosite	uh-NOR-thuh-syt	A mineral on the moon and on the earth. Part of Genesis Rock.
astronaut	AS-tro-naut	A person who has been trained to pilot space vehicles.
axis		An imaginary line passing through the poles of an object, such as a planet, about which it rotates.
Babylonians	bab-i-LO-nee-uns	People from the ancient country of Babylonia who divided the day into periods of twelves.
calendar	KAL-en-dur	A system of dividing the year into days, weeks and months.
capsule		The part of a spaceship which holds the instruments, animals and/or astronauts.
circumference	sur-KUM-fur-uns	The distance around a sphere.
counterclockwise		Any movement opposite to the usual direction of the hands of a clock.
crater	KRAY-tur	A cup-shaped hole on the moon's surface.
eclipse	ee-KLIPS	The temporary casting of a shadow by one heavenly body onto another.
foci		The two points about which an ellipse is formed.
Foucault, Jean	foo-KOH, JON	A French physicist who proved by means of a pendulum that the earth rotates.
Genesis Rock	JEN-uh-sis	A rock sample from the moon; thought to be as old as the moon itself.
Goddard, Robert H.	GOD-ard	American scientist: father of space rocketry.

Gregorian Calendar	greh-GOR-ee-un	The calendar that Pope Gregory had arranged in 1582. It is the calendar that is used today.
Greenwich	GREN-itch	The town in England through which the prime meridian passes.
hibernate	HY-bur-nayt	A response of some animals to low temperature: "winter sleep."
horizon	huh-RY-zun	The line where the earth and sky seem to meet.
International Date Line		The line along the 180th meridian of longitude. When crossing over it, you gain or lose one calendar day.
interval	IN-ter-vul	A period of time.
KREEP	KREEP	A moon rock which gets its name from potassium (K) rare earth elements (REE) and phosphorus (P).
latitude	LAT-i-tood	The distance measured in degrees north or south of the equator.
longitude	LON-ji-tood	The distance measured in degrees east or west of the prime meridian.
lunar	LOO-nur	Anything about the moon.
Mare Imbrium	MAH-ray IM-bree-um	One of the large plains on the moon. It is also known as the "Sea of Showers."
maria	MAH-ree-uh	The moon's basins, once thought to be seas, filled with basalt.
meridian	muh-RID-ee-un	An imaginary line running north and south through the poles. Also called a line of longitude.
orange-soil		A moon mineral tinted orange by titanium.
pendulum	PEN-dyou-lum	A heavy mass on a string or wire which is held from a fixed point to allow the mass to swing back and forth.
phases	FAY-ziz	The portions of the moon lighted by the sun as seen from earth.
prime meridian		The imaginary line which runs north and south and stands for 0° longitude.

pumice	PUM-is	A type of rock which resembles a sponge and was formed by volcanic action.
season		One of the four periods of a year. Each season means a difference in temperature and the length of day and night.
sextant		An instrument used to measure angles. It is used in navigation.
sidereal day	sy-DEE-ree-ul	The length of time of a day as figured out by the astronomers with reference to a star.
standard time		The division of the world into belts or zones, each 15° wide. The time changes by one hour from zone to zone.
tidal range		The difference in height between high tide and low tide.
tide		The rise and fall of the oceans' waters. Tides are caused mostly by the gravitational attraction of the moon.
topography	to-POG-ra-fee	The study of the surface features of an area.

ANSWER TO PUZZLE V, PAGE 87

1. **B**rahe, 2. galil**E**o, 3. fauc**A**ult,
4. new**T**on, 5. pto**L**emy, 6. k**E**pler,
7. eratosthene**S**
ANSWER: **BEATLES**

ANSWER TO PUZZLE V, PAGE 106

1. s**P**here, 2. t**I**de, 3. ph**A**se,
4. cresce**N**t, 5. **O**rbit
ANSWER: **PIANO**

UNIT IV

The man at the top left is Yuri Gagarin, the Russian cosmonaut. He was the first man in space. Next to him is Icarus. According to a Greek fable, Icarus flew too close to the sun and his wax and feather wings melted. An Apollo space capsule (center left) is shown as red hot as it reenters the earth's atmosphere. The pink bands (bottom) show a cross section of the Van Allen Belts which surround the earth. The satellite, Interplanetary Explorer (bottom right) proved the presence of the Van Allen Belts. On the television screen (right) is a picture of an astronaut on the moon. The moonscape is reflected in his helmet.

OFF INTO SPACE

UNIT IV

Off into Space

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19

TARGET
Why do we wish to explore space?

Our Interest in Space

1. WAX WINGS AND CHINESE ROCKETS

An ancient Greek fable tells the story of how a father and his son wished to escape from the Island of Crete. They made wings from feathers and wax. Then they stood into the wind and off they went, flying high in the air! But the boy flew too close to the sun. The heat of the sun melted the wax and he crashed to his death in the sea.

Fig. 144–1

In the year 1230, the Chinese used firecrackers (rockets) to shoot weapons at their enemies from far away. Between 1812 and 1814, a war raged between the Americans and the British. During the night of September 14, 1814, the British fired rockets at Fort McHenry near Baltimore, Maryland.

In the closing days of World War II, Great Britain and her allies were alarmed because Nazi Germany had developed the V-2 Rocket. This rocket was fired from Germany and landed in Britain, where it exploded. After the war, the Americans and Russians collected the information about rockets. They later decided to spend time, money and energy for more research on rockets. (See Fig. 159–2.)

2. BALLOONS AND JET PLANES

"But," you say, "we are already able to go very high up in the air. We have balloons and jet planes." Yes, we can go far up. But we cannot go far enough. Look back at the Chart of the Atmosphere (Fig. 4–1). Beyond about 30 500 m (30.5 km), there is very little air. Lack of air means that balloons cannot rise. There is no air pressure to lift the wings of a plane. There is not enough oxygen to ignite the fuel of the jet engines. So, you see, balloons and jets cannot take us into space. We must find something else to take us into space.

SPUTNIK I SATELLITE SEEN OVER NEW YORK

Oct. 14, 1957—For the first time since it was put into orbit, the Russian satellite Sputnik I was seen by New Yorkers. The Sputnik I was visible for almost five minutes in the skies over New York City —from 10:07 p.m. until 10:12 p.m.

Experts say that the Sputnik I varied in brightness from brilliant to very dim. The reason, they believe, is that the satellite is rotating as it circles the earth.

The Sputnik I will be visible tonight in the sky at almost the same time as last night. Look for a moving ball of light that fades and then becomes bright again.

3. THE SPACE AGE BEGINS

We cannot tell when or where the whole story began. It happened thousands of years ago when people first looked up into the heavens and wondered. But the latest chapter in our story began on October 14, 1957. On that day, the world was amazed by the newspaper and television headlines. Soviet Russia had fired a small ball or SPHERE (SFEER) into space. The ball was moving in a definite path, or orbit, around the earth. The new object had become, like the moon, a SATELLITE (SAT-uh-lite). The object was named SPUTNIK I (SPOOT-nik). Sputnik is the Russian word for a "friend on the path." Sputnik became a "friend" of the earth, as they both circled the sun.

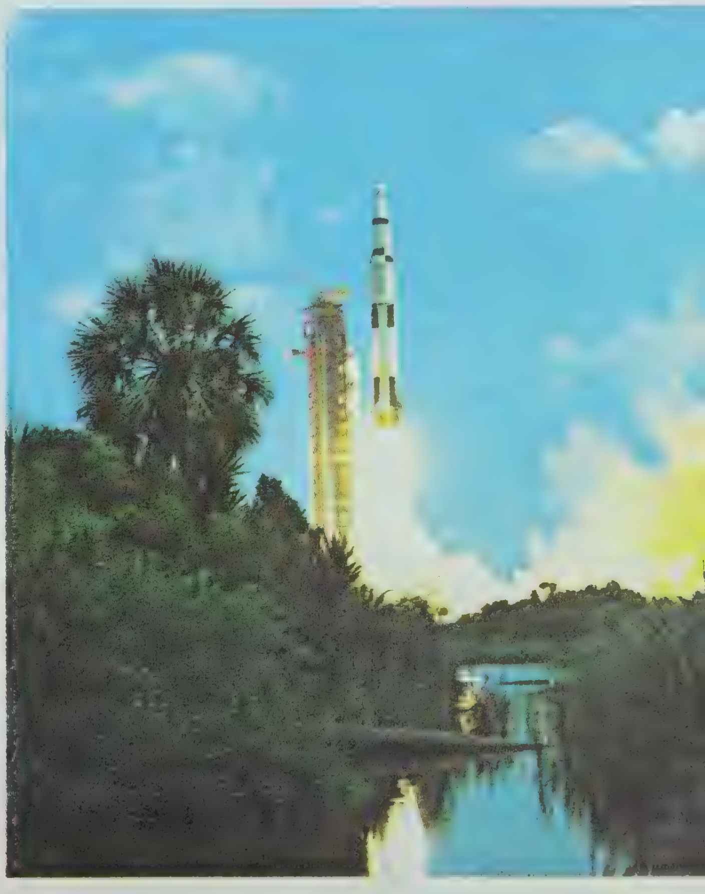


Fig. 145–1

A powerful rocket boosts a payload into space.

4. SPACESHIPS ARE DIFFERENT

A spaceship does not use an ordinary engine. A spaceship must be pushed or forced into the upper atmosphere. We say it must be *boosted.* What causes boosting? The spaceship is boosted up by a *rocket.* The rocket "shoots" the spaceship, much like a cannon shoots a cannon ball. The heavier the spaceship and the farther we want it to go, the stronger the rocket.

Space travel, then, requires three important things:

1. A powerful booster (the rocket).
2. The actual capsule or satellite (the payload).
3. A system for guiding and keeping track of the rockets.

5. WHERE DOES THE PAYLOAD GO?

If the rocket is strong enough, the payload will go into space, far above the earth's atmosphere. The payload may be a satellite which stays in the earth's orbit. It continues to circle the earth just like our moon circles it.

Some payloads are made to escape from the earth's orbit. Such capsules travel in space like our earth does. Rockets can also revolve around other planets. Some capsules or satellites are designed to land on another planet or on the moon. If the capsule hits the planet with a crash, we say it has made a *hard landing.* If it comes down gently, we say the capsule has made a *soft landing.*

Some capsules are *manned.* They can carry one, two or three passengers. These capsules go on a given mission and then return to earth. Usually they *splash down* into the ocean. However, in Russia the spaceships often come down on land.

Some capsules are built to explore the moon. When the astronauts in the capsule landed, they were brought down to the moon by a special vehicle called a LUNAR MODULE (MOD-yool) or LM. The lunar module is sometimes called the LEM or Lunar Excursion Module. When their mission was finished, the astronauts returned to the LM. The LM docked with the capsule. Then the LM was separated from the capsule. Only the capsule returned to earth by splashdown in the ocean.

6. A MEETING IN SPACE

The United States and Russia have been successful in having two capsules meet in space. This is called a RENDEZVOUS (RON-day-voo), the French word for a meeting or an appointment. On January 16, 1969, a new space advance was made. Two Russian spaceships had a rendezvous in space and docked (joined) their vehicles. Astronauts moved freely from one capsule to the other. In May, 1969, the United States docked a space capsule and a lunar module while orbiting the moon. In July, 1969, when the astronauts returned from the moon, they had to dock the LM with the capsule. This was the beginning of *space stations.*

YOU NOW KNOW

- Simple rockets were known a long time ago.
- Jet planes are useless in space because of the lack of air.
- Spaceships require a rocket which boosts the payload.
- Space capsules can meet in space.

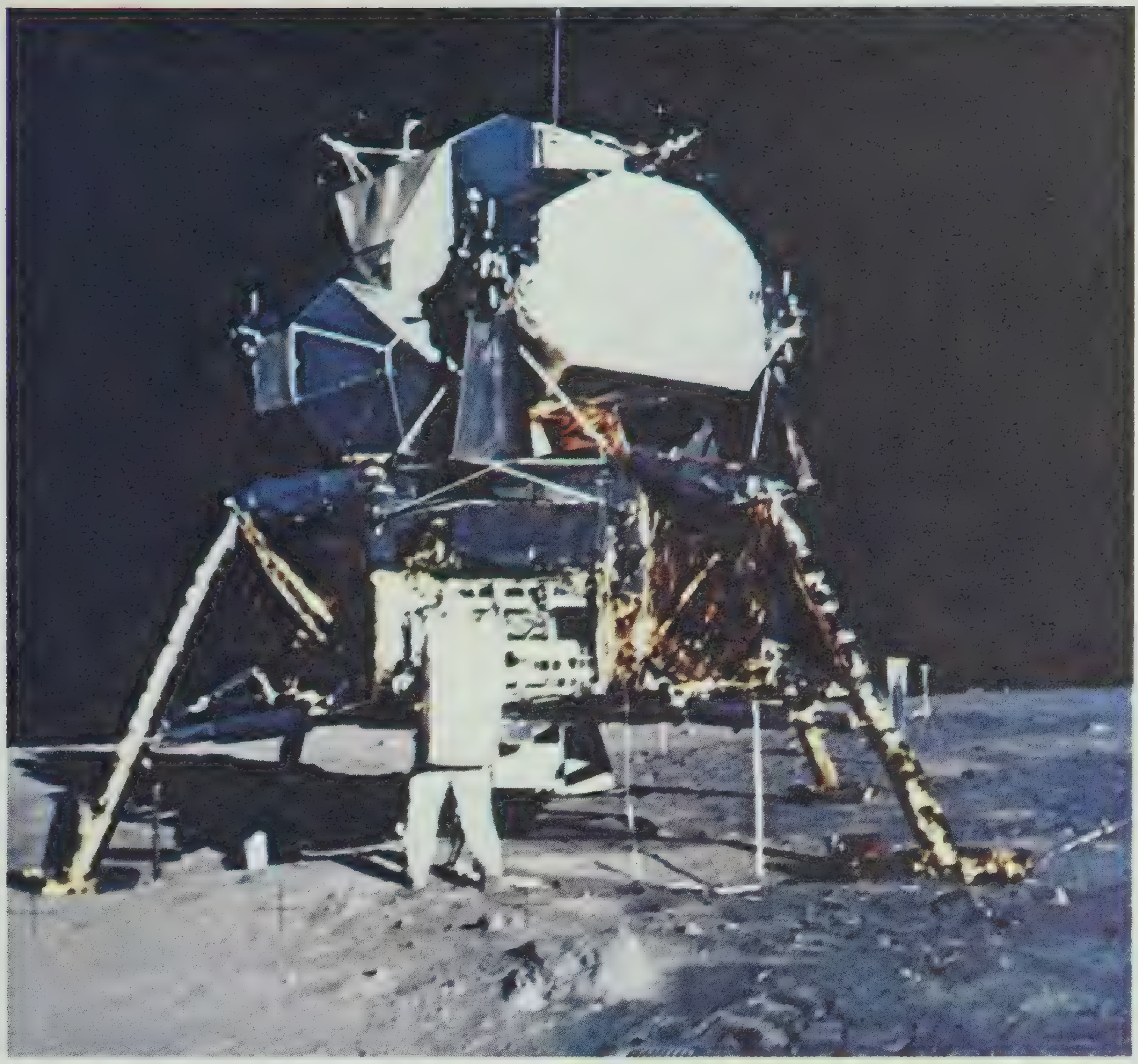


Fig. 147–1

This is the lunar module, "The Bug," that lands astronauts on the moon. How does "The Bug" leave the moon?

7. WHY DO WE WISH TO EXPLORE SPACE?

In the days of explorers such as Columbus and Magellan, some people could not understand the drive to explore an unknown world. Even after the early landings, there were some who thought we should abandon the new world. Our exploration of space is much the same. It offers opportunities to everyone, many of which are hard to predict. But even now, in the early days of this new age, there are already many benefits.

First, each space mission (also called a probe) has given us a great deal of knowledge about our own earth and its atmosphere. As satellites orbit the earth, their instruments send back information. For example, we have now seen pictures of the earth itself. We have learned more about the density of the upper atmosphere and the various temperatures at different levels. We have studied the effects of the earth's magnetism. We have learned more about radiation above the earth.

But there is more than that. On the practical side, the U.S. satellites *Tiros N* and *Nimbus* 6 are broadcasting weather observations to earth. Now we are able to predict weather on a worldwide scale. Have you heard of the Canadian satellite *Anik* and the U.S. satellite *Intelsat*? As they orbit in space, they receive radio, TV and telephone messages from one country and relay them to another country. Perhaps you have already seen a TV show via *Anik* or *Entelsat*.

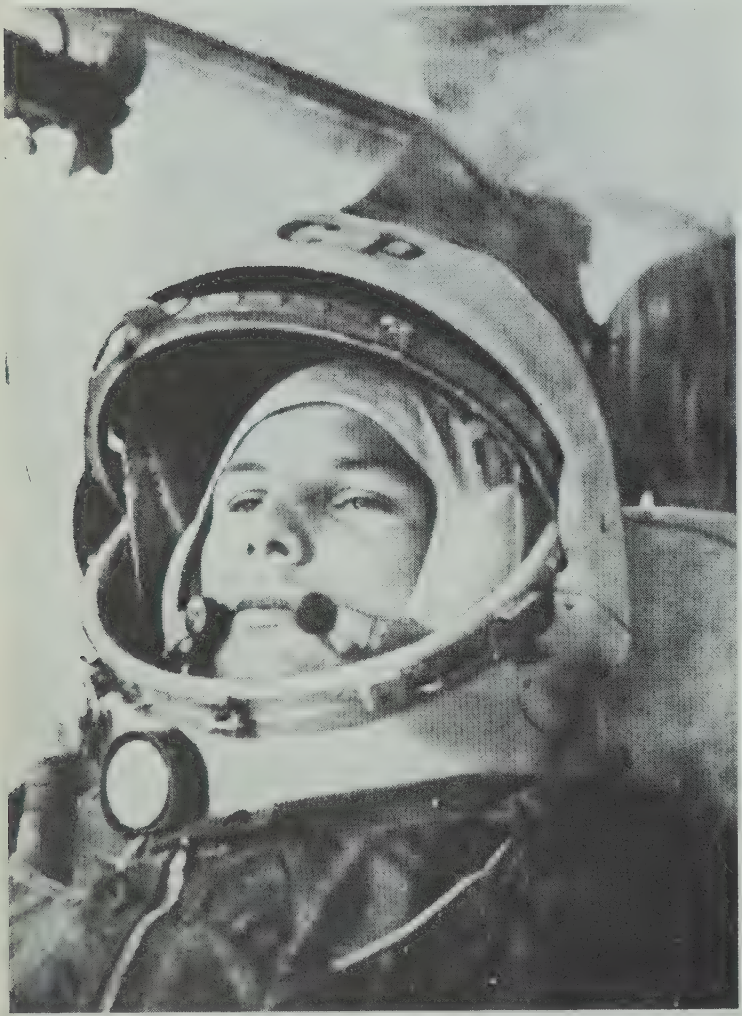


Fig. 148–1

Russia's cosmonaut, YURI GAGARIN (YOOR-ee ga-GA-rin), was the first man to enter space.

8. WHO EXPLORES SPACE?

Right now, space exploration is very expensive. Only wealthy governments can organize space probes. So far, only the United States and the Soviet Union have explored space. The United States maintains a separate branch of the Government called The National Aeronautics and Space Administration (NASA). This organization controls the construction, testing and launching of all space shots. NASA trains the astronauts (called cosmonauts in Russia) who go into space, and all of the ground control scientists.

Space shots in the U.S. are made from Cape Kennedy in Florida. In Russia, launchings are made in Central Asia.

9. OUR FUTURE IN SPACE

There are predictions that newspapers of the future will be beamed by satellite into your own home. Will you be going to Paris? The predictions say you may be able to get there in half-an-hour by rocket plane. Will you want to know the weather in Paris before you go? You may be able to turn your TV on and see it for yourself by satellite!

What happens after we have landed on the moon or on the planets? Can we expect to get more than knowledge? We are not yet able to answer this. We do not know that many elements on the earth are found on the planets. Are some precious ones, like gold and uranium more plentiful than on earth? Are there new elements and compounds we have never seen? These, of course, are answers we do not have as yet. Each planet may turn out to be a real storehouse of treasure. Some may turn out to be a new home for the people of Earth.

YOU NOW KNOW

- Space exploration will provide more knowledge about our earth and the universe.
- Satellites are already providing weather data and relaying radio and TV signals.
- The future may bring us to the planets where we may find great wealth and resources.

UNDERSTANDING WHAT YOU HAVE READ

I. What are the two main ideas in Chapter 19?

1. There are very good reasons for exploring space.
2. The Germans really started space exploration.
3. NASA will replace the National Weather Service.
4. Space exploration requires special vehicles.

II. In which paragraph do you find the answer?

1. Are rockets a new idea?
2. What is meant by the payload of a space shot?
3. Are all satellites designed for landing on planets?
4. What is the Early Bird?

III. Knowing What and Why

1. A jet plane is useless in the upper atmosphere because
    a. you can never make a strong enough engine.
    b. passengers would die at that height.
    c. jets cannot orbit.
    d. there is no air to support engine combustion.
2. A booster at Cape Kennedy
    a. fires a rocket into the air.
    b. blasts a capsule into space.
    c. controls the direction of Tiros I.
    d. changes the gravity of the earth.
3. A satellite in orbit
    a. must return to earth, sooner or later.
    b. can stay in orbit almost indefinitely.
    c. must get to the moon, sooner or later.
    d. uses a rocket to return to the earth.
4. A "soft landing" refers to
    a. landing without crashing.
    b. astronauts in the Pacific Ocean.

c. a satellite in orbit.
d. a rocket whose sound is muffled.

IV. True or false? Explain your answer.

1. Rockets only boost satellites. They go no place themselves.
2. All space exploration is really for war.

V. Give a Definition.

Write a simple, one-sentence definition in your own words for each of the following:

1. astronaut
2. rocket
3. booster
4. payload
5. rendezvous

VI. For the Science Reporter

1. Read about the German V-2 Rocket used in World War II. Report to your class.
2. Read about the ICBM and ABM. Report to your class.
3. Follow the TV pages of your newspaper. When an Early Bird program is announced, watch it.
4. Read about Cape Kennedy and its history. Report to your class.

VII. For the Collectors

1. Write to the National Aeronautics and Space Administration, Washington, D.C. 20546. Ask for free booklets about the work of NASA.
2. Collect clippings and pictures about space exploration. Cut up old newspapers and old magazines.

20

TARGET
How can we solve the problems of space travel?

Problems of Space Travel

1. MANY PROBLEMS TO SOLVE

Even if we want to put a satellite into space just to orbit the earth, many problems have to be solved. When we also want to send human beings into space and bring them back, the problems become even greater. The chart below tells you some of the problems.

SPACE TRAVEL PROBLEMS

1. Getting the payload into orbit.
2. Protecting the capsule or satellite in space.
3. Generating electricity for the capsule in space.
4. Solving the human needs of the astronauts.
5. Guiding the capsule in the right direction.
6. Returning the capsule safely to earth.

Fig. 151–1

One of the first passengers in space was Enos, an American monkey.

2. WHEN g-FORCE RISES

The rocket stands ready on its launching pad. The count-down is on. It's "6-5-4-3-2-1-0, lift off!" There is a mighty roar and the huge rocket rises.

What is the effect of such a violent explosion on the astronaut? As the rocket accelerates (speeds up) the pressure against his body is built up far beyond normal. The push is called *G* for gravity. Normal push of the earth on a body is 1 *G*. But on takeoff with such force, the push can rise to 10 *G* or 11 *G*. In Apollo 8, the capsule showed a force of 4*G*. In order to lessen the effect of this push, the astronaut lies on a special foam rubber chair.

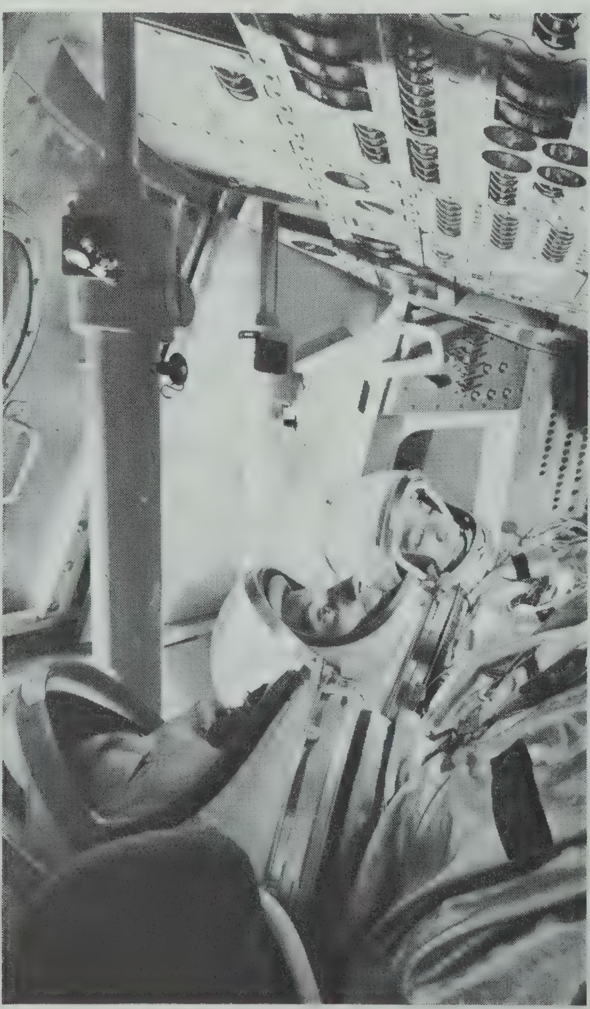


Fig. 152–1

Additional pressure on takeoff is lessened by having the astronauts lie on their backs.

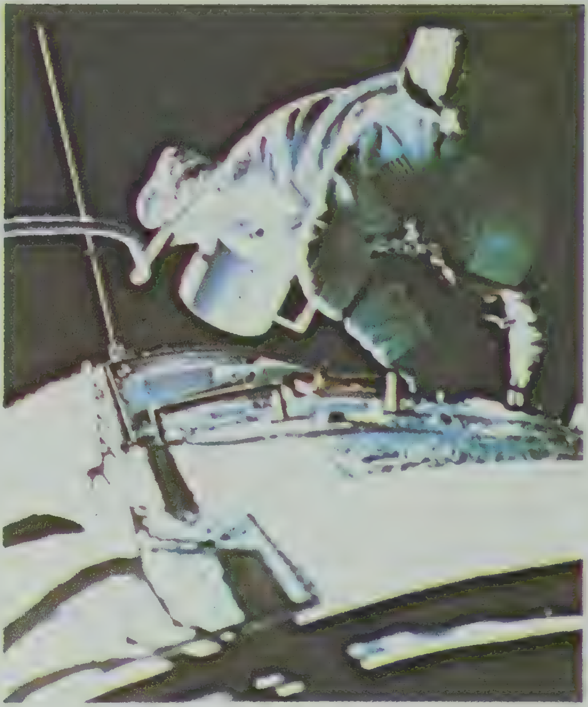


Fig. 152–2

Astronaut Ed White takes a "walk" in space. Why is he "weightless"?

3. WEIGHTLESSNESS

When the rocket engine is burned out, a strange thing happens. The astronaut is now in *free fall.* There is no push and no pull. The body and all the objects in the capsule have become *weightless.* A camera, put aside, will remain floating in mid-air. You cannot drink or eat in the usual fashion. The food must be squeezed into the mouth from plastic bottles and bags.

Is weightlessness dangerous? So far, it has had no bad effects on the astronauts. Of course, astronauts have not spent too much time in space.

Astronauts have reported some dizziness, but this fades away quickly. Of course, walking on the moon is different from walking on earth. When you stumble it is easier to get up. In later missions, a drop in the number of red blood cells was seen in the astronauts. All in all, weightlessness is something to which the body can adjust.

4. PRESSURE AND TEMPERATURE CONTROLS

On earth, we are under air pressure of about 100 k Pa (100 000 N/m^2). The drop in air pressure as we leave the earth is very great and very sudden. Such a sudden drop in pressure can kill a human being. The capsule and the space suits are both *pressurized*. This means that extra gas is pumped into them to raise the pressure.

Temperatures in space range from hundreds of degrees below zero to hundreds of degrees above zero. Again, the capsules and the space suits must have good temperature controls. In the Apollo 8 mission of 1968, the capsule temperature was kept at about 24°C.

The greatest problem from heat comes when the capsule re-enters the earth's atmosphere. The speed of 28 000 km/h rubs the capsule against the blanket of air and produces friction. Friction produces heat. The front of the capsule is fitted with a special *heat shield*. The heat shield is made of *heavy fiber glass layers*. It chars (turns smoky black), but does not burn. Even with the heat shield, the temperature in the Apollo 8 capsule rose to 67°C. upon re-entry. The space suits protected the astronauts from the inside heat.

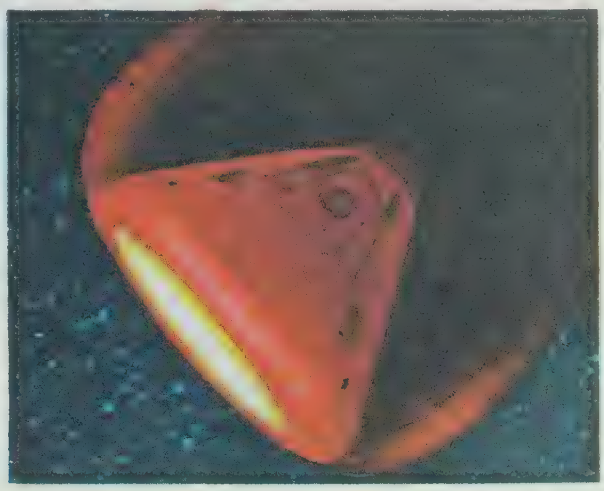


Fig. 153–1

The heat shield protects the capsule and astronauts from burning up. It can withstand temperatures of up to 2 760°C.

YOU NOW KNOW

- Problems of space travel are both mechanical (engineering) and biological (human life).
- Blast-off produces an increase in pressure (*G*-force). This is followed by weightlessness.
- Temperature and pressure are controlled by the space suits and the capsule.
- The heat shield protects the capsule against burning when re-entering the earth's atmosphere.

5. THE BREATHING PROBLEM

To provide the proper breathing atmosphere, pure oxygen is fed into the astronaut's helmet at a reduced pressure. At the start, the capsule is filled with a gas mixture of 60% oxygen and

40% nitrogen. This is to reduce the chances of another tragic fire which killed three astronauts in a ground test. After launching, the oxygen-nitrogen mixture is slowly released into space. About five hours after take-off, the capsule atmosphere is about 95% oxygen.

6. GENERATING ELECTRICITY IN SPACE

Burning fuel generates the thrust (force) to shoot satellites and capsules into space. What then? Where do they get the energy to operate the instruments, to take pictures and to operate their "life-support systems"?

Electric generators used on earth are too heavy for space missions. They need fuel and oxygen. The fuel is too heavy and there is no oxygen. Nuclear energy is not yet well-developed and may give off dangerous rays. Although some power can be gotten from specially designed batteries, that is not enough. What is left? If you guessed "*the sun*," you are right!

One source is the SOLAR CELL (SOH-lur sell). These cells are made of crystals of silicon and boron. When the crystals are exposed to sunlight, they set up a charge and generate electricity. In the 1973 *Skylab Mission* the wings of the capsule were equipped with about 74 000 solar cells. Two solar panels swung out to face the sun and pick up the rays. The two banks of solar cells could generate 10 500 W of power!

A second kind of power source is the FUEL CELL. The fuel cell uses gaseous oxygen and hydrogen and an *electrolyte* called potassium hydroxide. In addition to producing electricity, the cells produce pure water as a byproduct. The water is used for drinking, preparing food, and for cooling equipment.

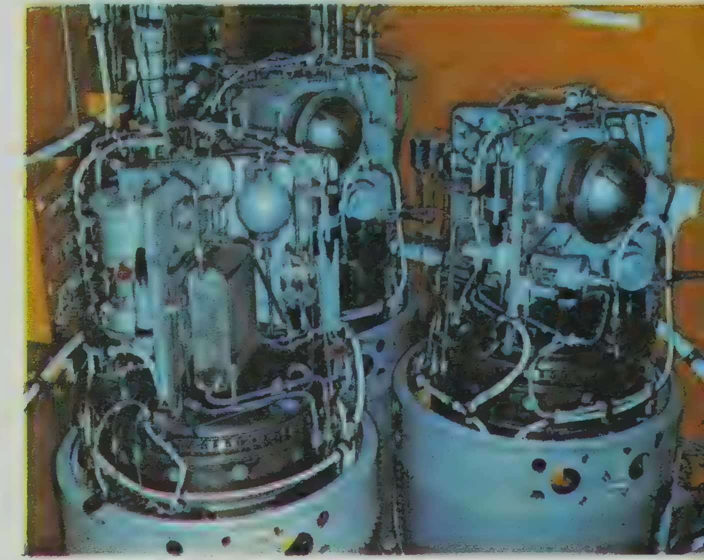


Fig. 154-1
Fuel cell power plants of the Apollo space mission. What are the advantages of the fuel cell?

7. THE DANGEROUS RAYS IN SPACE

In addition to the useful rays given off by the sun, there are also dangerous and deadly rays. We do not receive the dangerous *X rays* and ultraviolet rays because our atmosphere filters most of them out. However, up in space, there is no atmosphere. These rays can destroy the materials of the capsules and kill human beings. However, capsules are protected from these dangerous rays by special shields.

The invisible rays form zones called the *Van Allen belts*. The belts are about 6400 km thick and about 800 km above the earth's surface. Scientists believe the rays are clumped together this way by the earth's magnetism. Since the Van Allen belts are now charted, it may be possible to speed through them where they are thinnest. In the Apollo 8 mission of December, 1968, for the first time man passed through the Van Allen belts. Apollo 8 avoided the core of the belts and got through safely.

8. THE "LIVING ROOM" OF A SPACECRAFT

You already know that the rocket boosts a payload into space. In an unmanned flight, the payload is only a satellite. In a manned flight, such as Apollo, there are three sections to the payload. The topmost section is the Command Module (CM). Behind the Command Module is the Service Module (SM), which is a sort of storage room for rockets, fuel cells, oxygen and water. Behind this is the Lunar Module (LM), which was used when the shot landed on the moon.

The CM is the "living room." It is in this area that the astronauts work, eat and sleep. After five hours, they come out of their space suits and helmets, put on fatigue clothes and are ready for work. The capsule, you remember, is pressurized and its atmosphere is about 95% oxygen.

The CM is the nerve center of the spaceship. The instrument panel contains hundreds of dials for control and navigation. The first manned capsule, Mercury, had as much space as a phone booth. Gemini, the next one, was like the front seat of a foreign car. Apollo is like a station wagon.

The Apollo CM is cone-shaped, about 3.4 m high and about 4 m in diameter. It weighs about 5909 kg. It has been described as a "room with a view." The CM is the only section that returns to earth. The SM is cast loose into space before re-entry. In moon-shots, after the LM has brought the astronauts from the capsule to the moon and back, it is detached and left to orbit the moon or sent crashing back into the moon's surface.

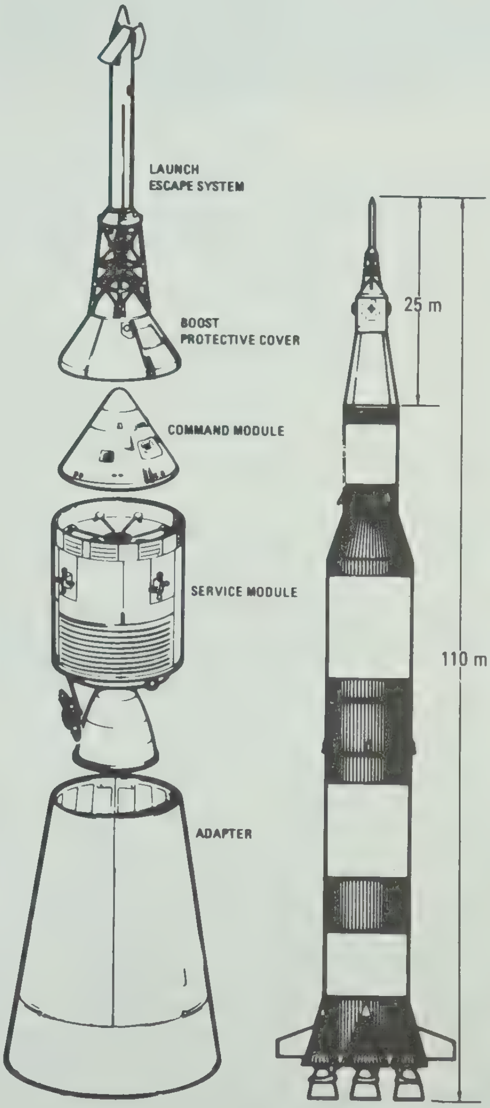


Fig. 155–1

The modern Apollo mission is a "luxury" ship compared to early models. Many stages are used to put the Command Module into orbit.

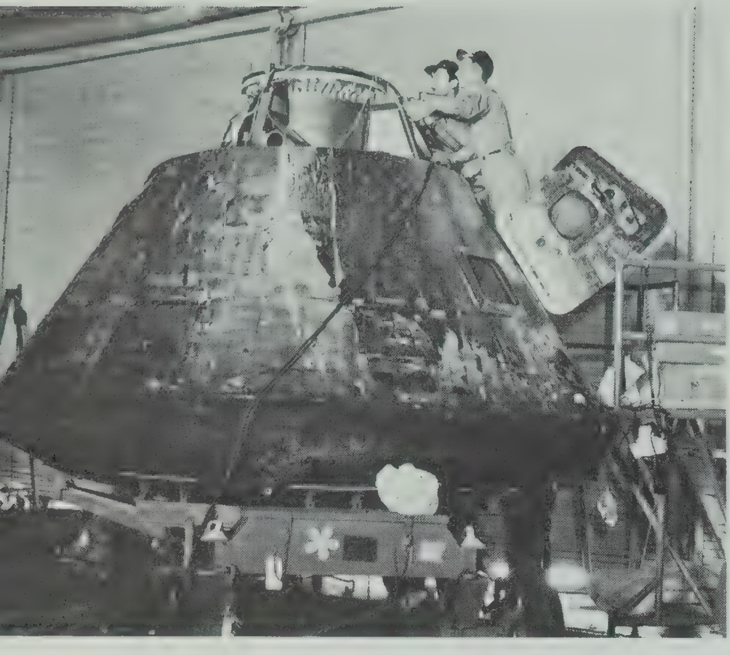


Fig. 156–1

Astronauts Cernan and Young inspect the Command Module of Apollo 10. Notice the size of the module compared to the astronauts.

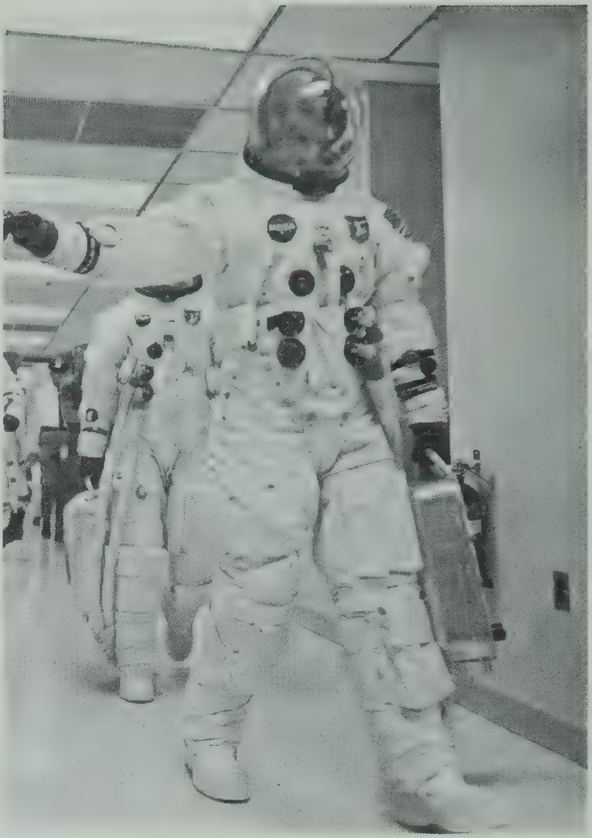


Fig. 156–2

This space suit weighs 25 kg. It can withstand temperatures of up to 1 093°C. What is in the "suitcase"? Why are they wearing masks?

9. THE SPACE SUIT

A space suit has to be strong enough to protect the astronaut, but not too heavy for him to carry. The space suit used on Apollo 7 was made from a material called Beta cloth. It contained 27 different fire-proof materials. A space suit has easy-to-turn joints at the knees, elbows and shoulders. It also has a device for water-cooling, and a fiber glass helmet which is fed oxygen. The carbon dioxide is breathed out through a hose. It is passed through a special filter to prevent poisoning of the astronaut's lungs.

YOU NOW KNOW

- The Command Module is the "living room" of a space capsule.
- The space suit protects the astronaut.
- The capsule and space suit have special atmospheres. The capsule is pressurized; the atmosphere is 95% oxygen.
- The dangerous zone of cosmic rays called the Van Allen belts has been passed through safely.

UNDERSTANDING WHAT YOU HAVE READ

I. What are the two main ideas in Chapter 20?

1. Space travel can help solve problems for mechanics and biologists.
2. A space capsule must provide a healthful atmosphere.
3. Weightlessness is not a difficult problem for astronauts in space.
4. So far, no bad effects have come to animals in space.

II. In which paragraph do you find the answer?

1. What gases fill a space capsule?
2. What are the Van Allen belts?
3. In which vehicle did the astronauts land on the moon?
4. What is a heat shield?

III. Knowing What and Why

1. The G-force in a space capsule is greatest
   a. when the capsule comes back to earth.
   b. as it orbits the earth.
   c. as it orbits the moon.
   d. when it moves out to Mars.
2. Astronauts rush through the thinnest part of the Van Allen belts to
   a. avoid weightlessness.
   b. reduce the danger of radiation.
   c. prevent the capsule pressure from falling.
   d. avoid shock to their hearts.
3. When astronauts have to sleep, they
   a. go to the lunar module.
   b. lie in a hammock in the Command Module.
   c. wait until they get down to earth.
   d. move into the Service Module.
4. The heat around a capsule coming back to earth
   a. results from the rocket's ignition.
   b. is not very great.
   c. builds up by friction.
   d. is now known to have been untrue.

IV. True or false? Explain your answers.

1. Astronauts are picked mostly for their physical strength.
2. In weightlessness, there is no "up" and no "down."
3. An astronaut who leaves the capsule is as good as dead.

V. Explanation, Please

1. Why do astronauts squeeze food into their mouths?
2. Why do astronauts lie on a couch during take-off?
3. Why is a space suit so complicated?
4. Why don't most of the cosmic rays from the sun reach us on earth?

VI. Match the words in *Column A* with those in *Column B.*

A

1. Van Allen belts
2. Lunar Module
3. Beta cloth
4. free fall
5. Command Module
6. Apollo mission
7. V-2
8. heat shield

B

a. X ray
b. fiber glass
c. astronaut's living room
d. weightless
e. rocket
f. moon taxi
g. blast-off
h. space program
i. space suit
j. cosmic rays

21

TARGET
How do rockets get the force to go into space?

Rockets and Their Thrust

1. LOOKING BACK . . .

We are held on the earth by gravity. For a satellite or capsule to be able to enter space, it must be able to escape from the earth's surface. The rocket that lifts the capsule or satellite must be strong enough to push or thrust the payload through the atmosphere, away from the direct pull of the earth. It must also push the payload in just the right direction and at the correct angle to get it into orbit.

2. ACTION AND REACTION

Have you seen a garden sprinkler rotating round and round? What makes it spin? It is explained by one of Newton's Laws of Physics: *To every action, there is an equal and opposite reaction.* The water comes out of each jet. This is an action. The sprinkler moves in the opposite direction. This is the reaction. When a rifle fires a bullet, the rifle kicks back. This is an example of an action and a reaction.

DO AND DISCOVER

Investigation 10: How can we show jet action?

What you do:

1. Get an oval shaped balloon. Blow it up and mount it as shown in Fig. 159–1.
2. Let the air out suddenly.

What you see:

The balloon moves in the direction opposite from the "jet."

What you learn:

Any enclosed container from which a jet of air rapidly escapes causes the container to move in the opposite direction.

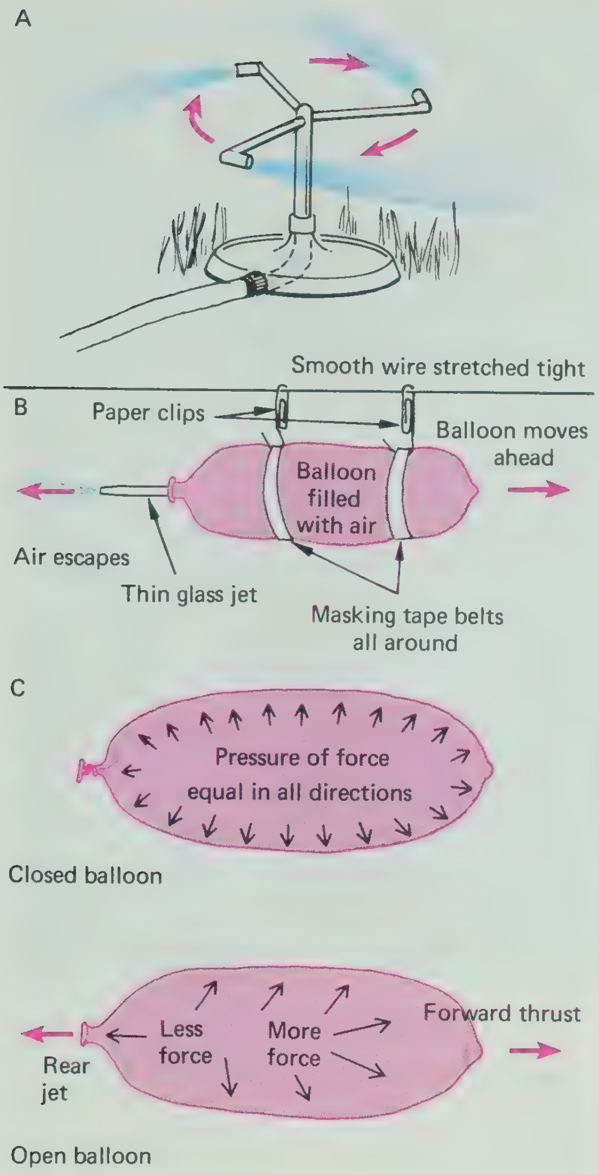


Fig. 159–1

Where is the greater force in the open balloon?

3. BUILDING A ROCKET

Dr. Goddard built the first liquid fuel rocket. (See Page 121.) But how did it work? Look at Fig. 161–1. This shows the scheme of a rocket. It shows a cylindrical pipe. Suppose we stand this pipe on a table. We fill it with some kind of fuel and ignite it. The burning fuel produces very hot gases. Now, if you let these hot gases escape from the bottom, the rocket will exhaust the gases through the nozzle. A thrust will develop at the top. The rocket will be boosted up and hit the ceiling. This is very dangerous. *Do not try to make your own rockets!*

Rockets are also called *launch vehicles.* The launch vehicle is long and slim to reduce friction. It is strongly built to withstand the explosion. Inside of its frame, there is a combustion chamber. The chamber is filled with a *fuel* and a material called an *oxidizer.*

Rockets stand on a *launching pad.* Beside the rocket are vertical towers called GANTRIES (GAN-treez) with elevators. These allow workers to go

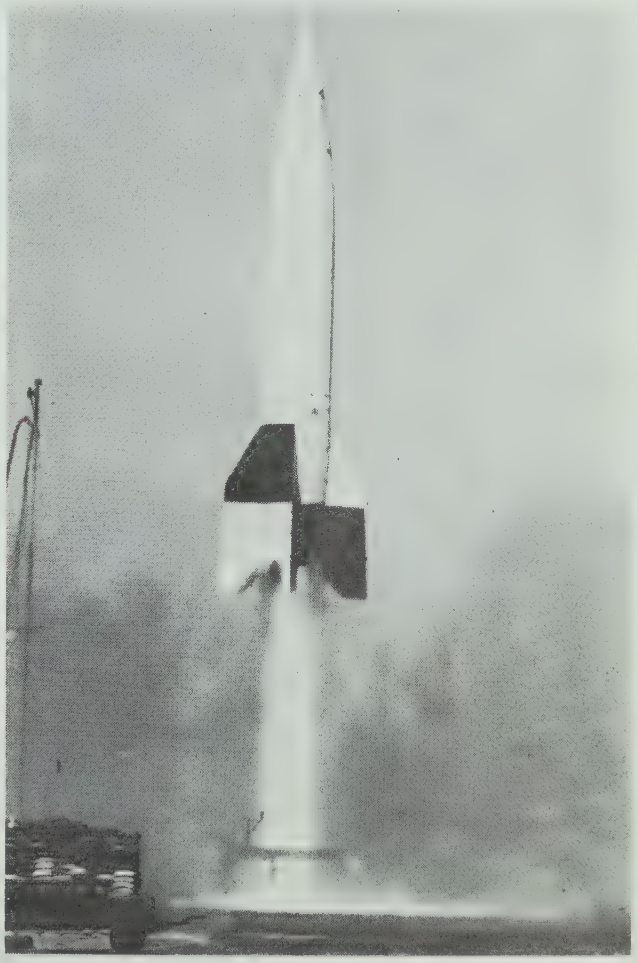


Fig. 159–2

V-2 Rockets were fired from Germany against Britain towards the end of World War II.

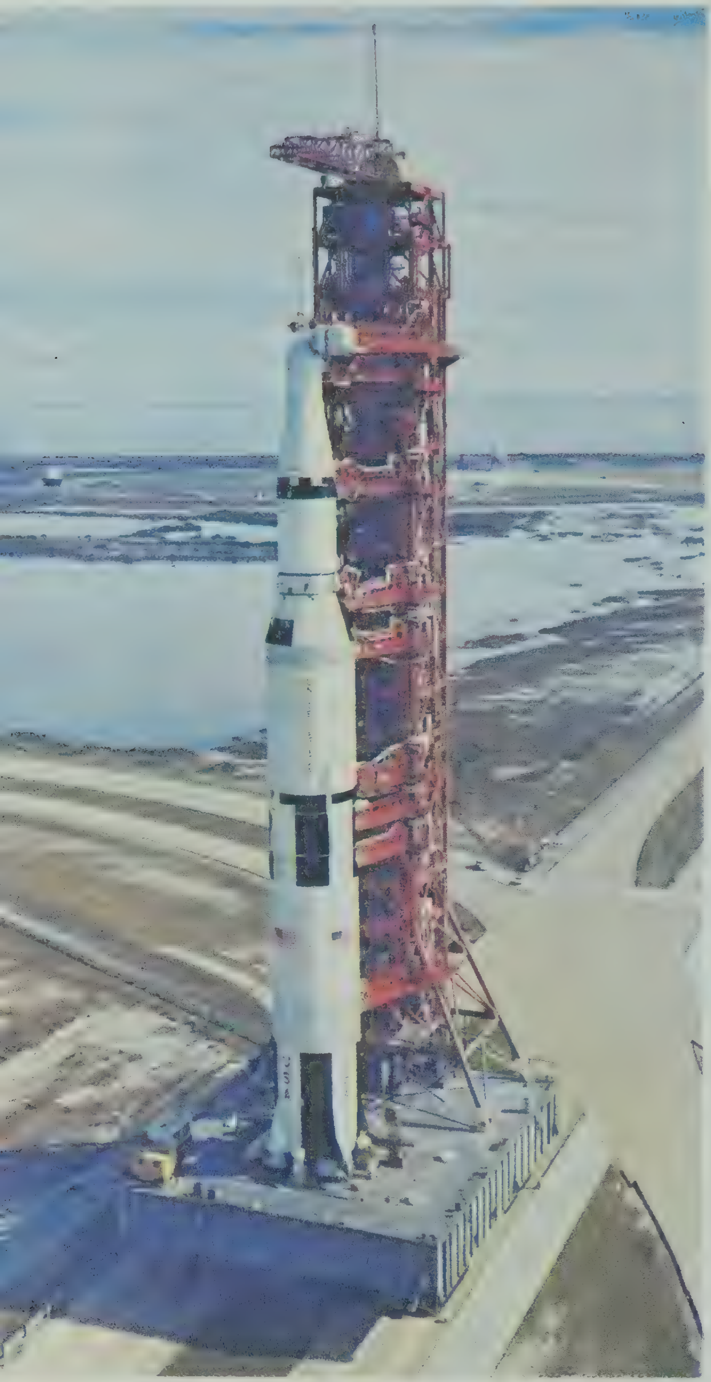


Fig. 160–1

A rocket stands on the launching pad ready for lift-off. How does Newton's Law of Action and Reaction explain why the rocket leaves?

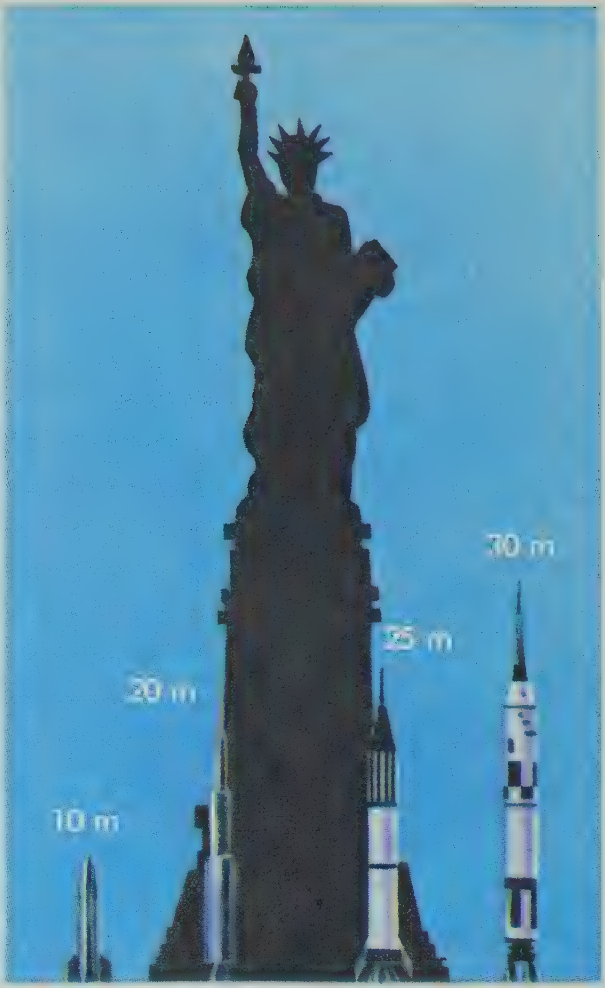


Fig. 160–2

Rockets come in different sizes.

up and down to work on the rocket and to deliver materials. Before the launch, the gantries are moved away. Then the countdown begins. "5-4-3-2-1-0-lift off!" The fuel ignites; there is a rush of flame and a loud roar as the giant lifts off and away.

YOU NOW KNOW

- Rockets work on the idea of Newton's Law of Action and Reaction.
- A rocket contains a combustion chamber in which fuel and an oxidizer combine to form hot gases which propel the rocket.
- Hot gases, escaping from the rear jets of a rocket, drive the rocket upward and away from the earth.

4. FUELS FOR ROCKETS

What kind of fuels do rocket engines burn? Rockets can burn either liquid fuels or solid fuels. So far, most rockets use liquid fuels. The fuel is combined with another chemical called an oxidizer. The mixture is called a PROPELLANT (pro-PEL-unt). In the rocket engine, no spark is needed as in an automobile. The two chemicals ignite automatically when they come in contact with each other.

Typical Fuels	Kerosene Alcohol Liquid Hydrogen
Typical Oxidizers	Liquid Oxygen (LOX) Nitric Acid Nitrogen Tetroxide Ammonium Perchlorate
Liquid Fuel + Oxidizer	= Burning Propellant

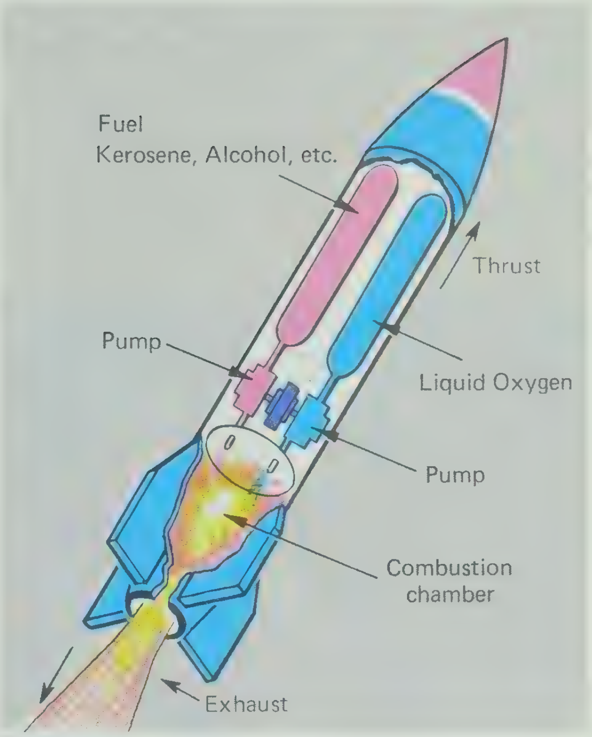


Fig. 161–1

In Apollo 7, the first stage rocket engine used 159 000 L of kerosene as the fuel. The oxidizer was 253 600 L of liquid oxygen (LOX). The LOX was kept at −182°C. The second stage used 242 000 L of liquid hydrogen and 75 700 L of LOX.

5. ROCKETS IN STAGES

Can you build a single rocket strong enough to boost a capsule into orbit, or way up to the moon? The answer is, not yet. It is rumored that the Russians are building a rocket with a thrust of 6.4 million kilograms, enough to blast a capsule to the moon. So far, however, this is experimental. In the meantime, a good method is to use rockets with two or three stages. Let's see how these work.

You must remember that a rocket needs much force and much speed. You can get these only by building very strong and very heavy rockets. As the rocket rises, the fuel is burned. The tanks remain empty. The rocket is then carrying useless mass. The solution is to have a big heavy rocket at the bottom, a second smaller rocket on top of this and a third, still smaller rocket on top. In other words, there are one-stage rockets, two-stage rockets and three-stage rockets. Saturn IB (See Fig. 162–1) was a two-stage rocket. Saturn V, the Apollo 11 booster, was a 3-stage rocket.

Saturn V, a 3-stage rocket, had five engines in Stage 1, five engines in Stage 2, and one engine in Stage 3. Each time a rocket stage dropped away, the entire vehicle became lighter. Each later stage needed less power because it was farther away from the earth's gravity and its load was lighter. The stages were fastened together with bolts. At the right time, the bolts were exploded by electricity and the stages separated.

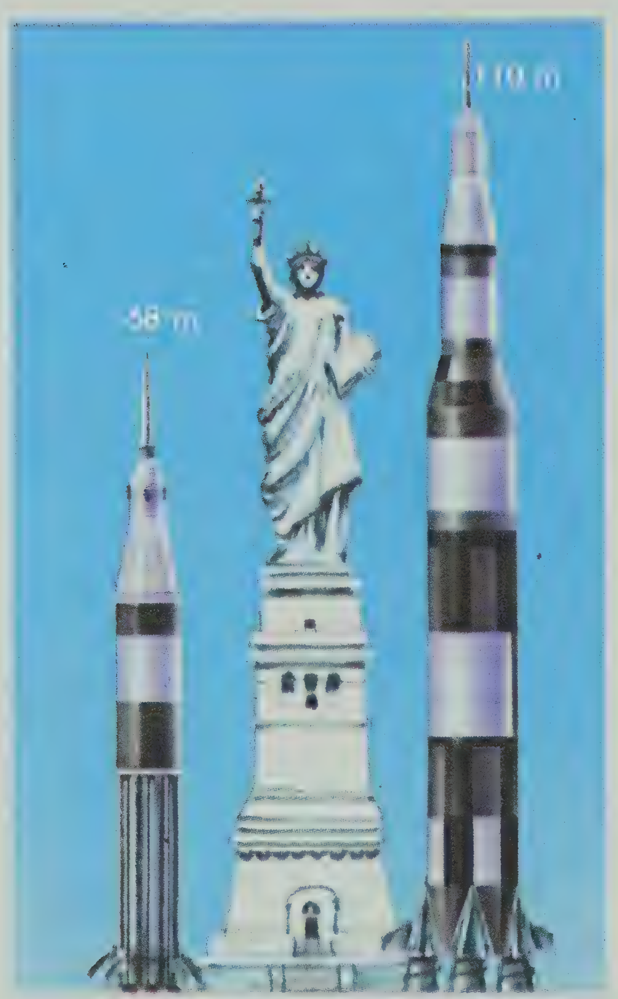


Fig. 162–1

Saturn IB (left) was the 2-stage rocket which lifted Apollo 7 in October, 1968 with a thrust of 726 400 kg. Saturn V (right) lifted the Apollo 8 in December, 1968 for a moon-orbit flight. It had a thrust of 3.4 million kilograms. The Saturn V also lifted the Apollo 11 which landed men on the moon.

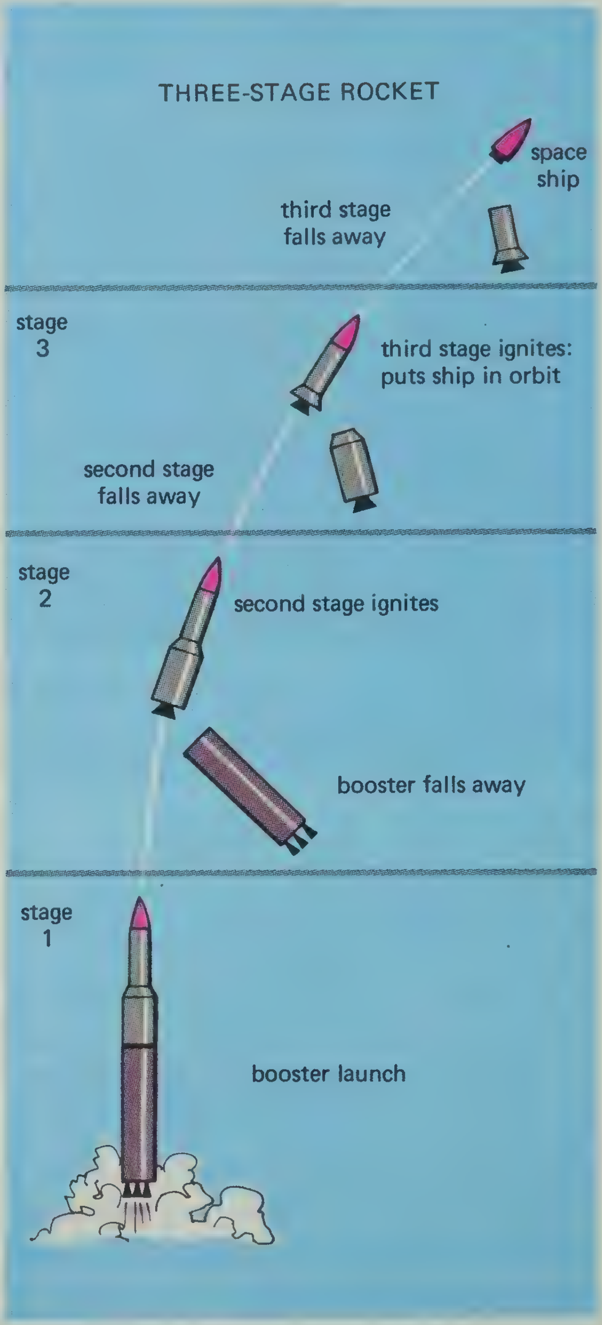


Fig. 162–2

Can you explain why the later stages are smaller than the earlier ones? Does this change in each type of rocket? Why?

YOU NOW KNOW

- Rockets use propellants which are mixtures of a fuel and an oxidizer. Most rockets use liquid fuels.
- Propellants ignite on contact. The hot gases develop force or thrust.
- Rockets are built in stages to lighten the vehicles and give added force far away from the earth.
- Saturn V consists of the Booster, Stage 2 and Stage 3.

UNDERSTANDING WHAT YOU HAVE READ

I. What are the two main ideas in Chapter 21?

1. Rockets are very old in theory.
2. Russian space rockets are very powerful.
3. Rockets work on the idea of action and reaction.
4. Rocket fuels are burned with oxidizers.

II. Explanation, Please . . . answer in one or two sentences.

1. What is thrust?
2. Why are spark plugs not used in space rockets?
3. Why are rockets built in two or three stages?
4. What is the value of dropping off the burned-out rockets?

III. Knowing What and Why

1. A propellant is
    - a. a mixture of a fuel and an oxidizer.
    - b. the special gas used in astronauts' helmets.
    - c. a kind of booster rocket.
    - d. the Ground Control Officer at Cape Kennedy.
2. LOX is used in space capsules
    - a. as a simple, digestible food.
    - b. for keeping the blood pure.
    - c. to prevent space nausea.
    - d. as an oxidizer of fuel.
3. Saturn V, the giant booster for Apollo 8,
    - a. had three stages.
    - b. burned on the launching pad.
    - c. was recovered in the Pacific Ocean.
    - d. was designed by Goddard himself.

IV. True or false? Explain your answers.

1. Rocket thrust is measured in kilograms.
2. The first stage booster rocket is the weakest of the three.
3. Gravity of the earth is unimportant when designing a rocket.

V. Which word does not belong with the others? Explain your answer.

Example: knife, hammer, fork, spoon. *Hammer* does not belong; the other three are eating tools.

1. Goddard, Newton, Van Allen, Gagarin
2. gantry, launch vehicle, rocket, orbit
3. kerosene, gasoline, alcohol, liquid hydrogen
4. Vanguard, Titan, Liberty, Saturn
5. propellant, cosmic rays, kerosene, LOX

VI. For the Amateur Scientist

Repeat the experiment in Paragraph 2.

1. Blow up the balloon with hot steam. What happens?
2. Blow the balloon up halfway. Then blow it fuller. What difference does it make?

22

TARGET
Why does the payload stay in orbit?

Exit from Earth—Entrance to Orbit

1. PUSH AND PULL

A rocket has launched a capsule to 325 km above the earth. Now Stage 2 or Stage 3 fires and the capsule separates from the rocket. The rocket has given the capsule a giant push, or thrust. But the earth, because of its gravity, is always pulling on the capsule. What will happen to the capsule? If the capsule can exert a force greater than the force of the earth's gravity, it can move out and away. This, then, is one of the secrets of space travel. A capsule must develop a thrust strong enough to overcome the earth's gravity. It can then escape from the earth's surface and is free to travel in space.

2. OUT AND AWAY

In Fig. 165–1, a cannon fires a shell from a tower 325 km high. (Of course, there is no such tower.) The shell should fly straight out, horizontally. But does it really? Not for long. Once again, we return to one of Sir Isaac Newton's laws. It states that an object in motion continues to move in a straight line at a steady speed *unless some force acts on it*. What is this force? Yes, it is the earth's gravity. The shell begins to move in a curved path, curved just like the earth (A) and quickly falls back to earth. Put more force into the cannon and the shell will travel farther. Again, it is on a curved path (B). Again, it falls to the earth. Try more force. The shell travels the curved path (C) and falls again. What now?

Instead of a cannon on a 325 km-high tower, the capsule is pushed from a rocket. The thrust of the rocket is very powerful. It is so powerful that the capsule now travels at a speed of 28 000 km/h. (Almost 8 km/s; about 467 km/min.) This is the speed at which the capsule orbits the earth. The capsule is trying to fly away in a straight line. But it can't because the earth's gravity pulls it into an elliptical orbit. It is just like our moon. The capsule will continue to orbit the earth forever unless another force acts on it.

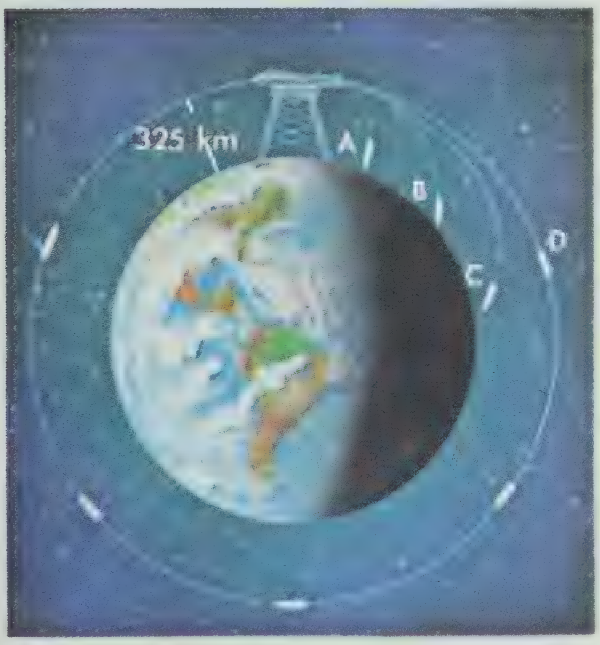


Fig. 165-1
What speed is needed to place the capsule into Path D?

3. OUT OF THE EARTH'S ORBIT

So far, you have seen how the capsule moves away from the earth's surface. The capsule is still a "prisoner" of the earth's gravity in its orbit around the earth. But now we wish to go to the moon. You have already used the words *escape velocity*. That is the speed needed for a body to completely get away from another body in space.

The capsule is orbiting at a speed of 28 000 km/h. The rocket gives it an extra thrust. The capsule speeds up to 38 900 km/h which is the earth's escape velocity. The capsule, after some time, comes closer to the moon. Now, the moon's gravitational pull has a greater effect on the capsule. The capsule is now a "prisoner" of the moon and orbits around it. Because the moon's gravity is weaker than that of the earth, the capsule's speed in lunar orbit is less than it is in earth's orbit.

4. CONTROLLING THE CAPSULE

When the capsule or satellite orbits the earth, there is no control. This may be all right for an unmanned satellite. But what about a capsule with passengers? Can they change the capsule's speed? Can they move from side to side? Can they change the capsule's orbit?

The answer to all of these questions depends on speed. As long as the capsule moves at the speed of 28 000 km/h, it will move in the same direction and in the same orbit around the earth. To change any of the motions, you must change the speed of the capsule. Capsules are provided with small rocket engines on the outside. By firing these rockets at the right time, the capsule can turn, slow down, or roll. When a capsule is ready to come down, it turns so that its rounded end faces towards the earth. Rockets are fired to reduce the speed of the capsule as it re-enters the earth's atmosphere. These are called the *retro-rockets*.

YOU NOW KNOW

- If a thrust can speed a body to 28 000 km/h, that body will escape the earth's surface and orbit around the earth.
- Orbiting capsules can be directed by firing small, outside rockets.

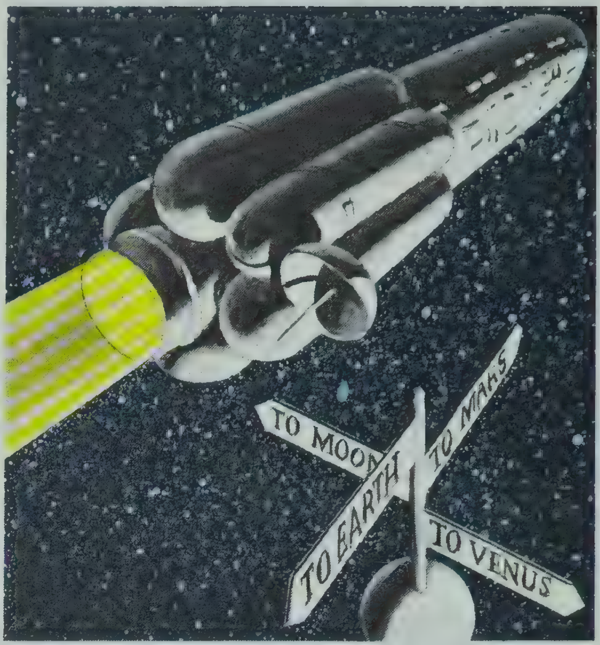


Fig. 166–1

5. FINDING YOUR WAY IN SPACE

There are no road signs in space. How do spaceships know the proper direction? They find their way by navigation. There are several systems of navigation or guidance.

To find your way in space means you must have the right instruments. The astronauts also use sextants to "shoot the stars." The sextants measure angles and altitude of star positions. This tells the astronauts their position. It also means that someone on the ground can give you directions or control you. NASA has set up many *tracking stations*. Such stations are located around the world, on land and on sea. They use radio, TV and radar signals to track the spaceship. These stations communicate with

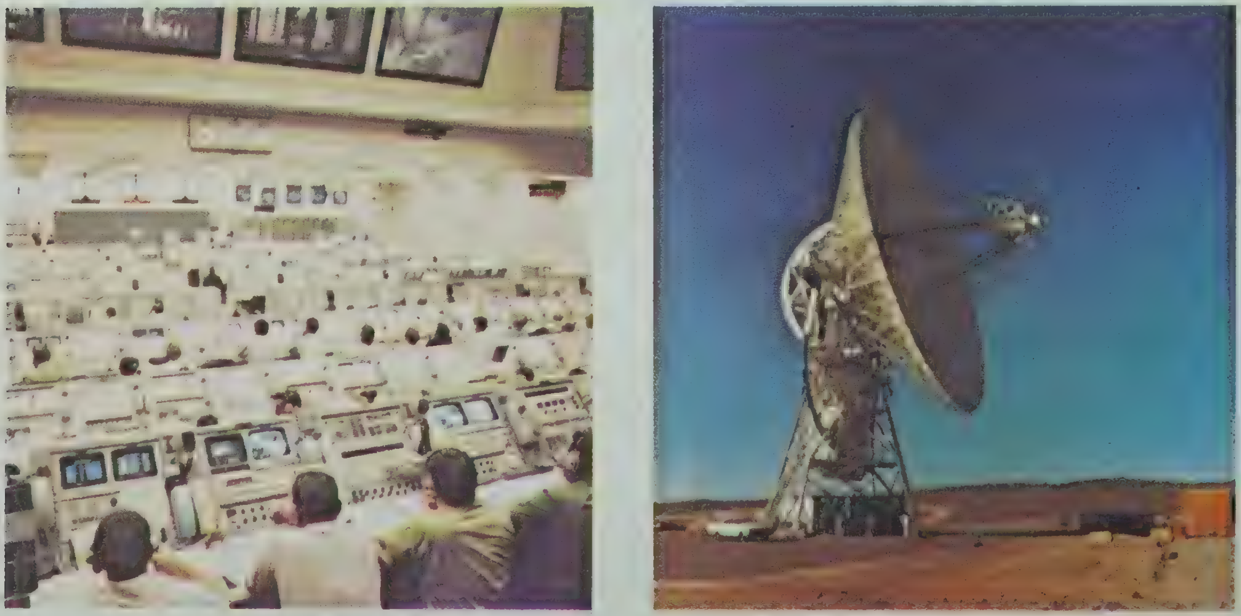


Fig. 166–2

Ground Control collects signals from the spaceship and from tracking stations around the world. The computers (mathematical machines) put the data together to help navigate the capsule. The radio antenna is 64 m in diameter.

Ground Control at Cape Kennedy. Ground Control is in constant communication with the spaceship and advises it as it travels in space. Did you know that it is possible to measure an astronaut's heartbeat all the way from space? Instruments, attached to his body or in his space suit, send signals to tracking stations which are then sent to Ground Control.

6. BACK TO EARTH

Re-entry into the earth's atmosphere means several things:

1. To slow down into earth's gravitation pull.
2. To stop the capsule from burning up from friction.
3. To land in the right place.
4. To be picked up (recovered).

To slow down, the retro-rockets at one end of the capsule are fired. These rockets are mounted so that their thrust will be in the opposite direction of the capsule's movement. The result is a reaction. The capsule "kicks back" and slows down. Now the capsule is moving at less than 28 000 km/h. The retro-rockets slow the capsule as it falls to earth.

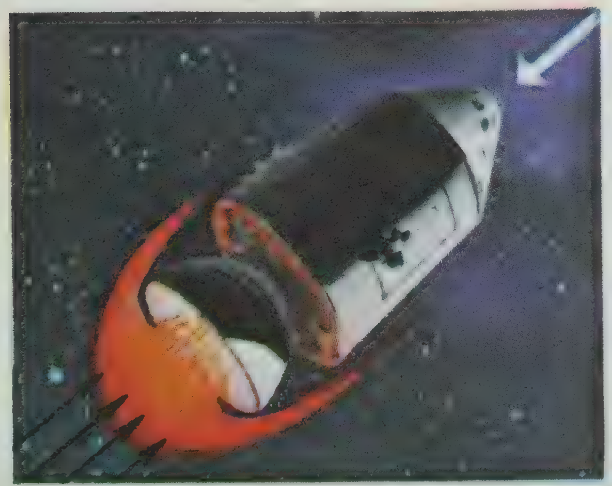


Fig. 167–1

Retro-rockets help to slow the capsule.

The capsule is still moving very rapidly. The friction of the atmosphere on the capsule is producing great heat. You remember that the capsule has now been turned. The heat shield gets most of the heat and may even become charred. The temperature in the capsule rises. But the space suits are on again. Since the space suits can withstand temperatures up to 1093°C, the astronauts are not very uncomfortable. At about 3050 m from the ground, three parachutes pop open and slow the capsule still more. Then the capsule splashes into the ocean. The astronauts are back on earth!

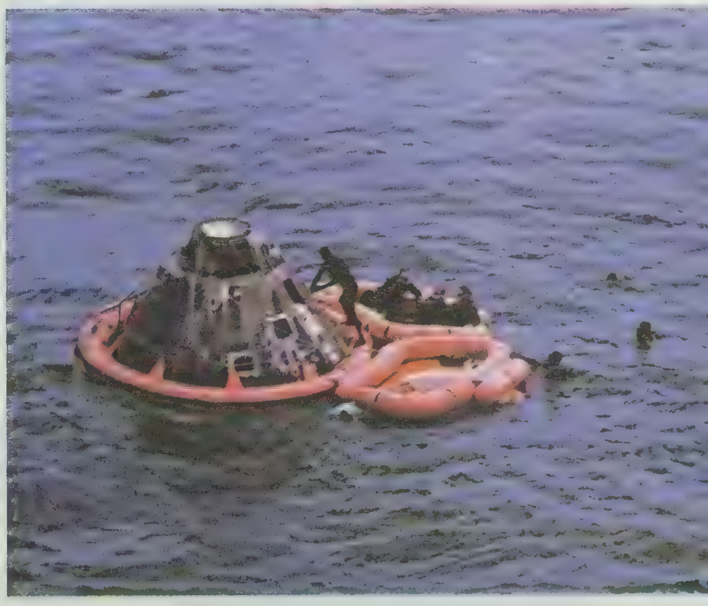


Fig. 167–2

These astronauts, having splashed down in the Pacific Ocean, are ready for recovery.

7. RECOVERY

The spot chosen for splashdown is called the *recovery area.* A recovery fleet of ships and helicopters wait for the capsule. Tracking devices tell the fleet precisely where the capsule lands. The astronauts open the hatch and come out on a rubber life raft. Helicopters pick them up and bring them to the ship.

The capsule is a precious article. It contains all the instruments needed for further study. Special divers called frogmen jump into the water to fasten cables and an inflated raft around the capsule. Then helicopters raise it out of the sea and take it to the recovery ship.

8. ROBOTS AND PROBES AND MISSIONS AND SKYLABS

When newspapers describe space exploration, they often use the words in the Paragraph 8 title. What do they mean? How do they differ? First, reread Paragraph 7, Chapter 19. You have now reviewed why we wish to explore space. But how?

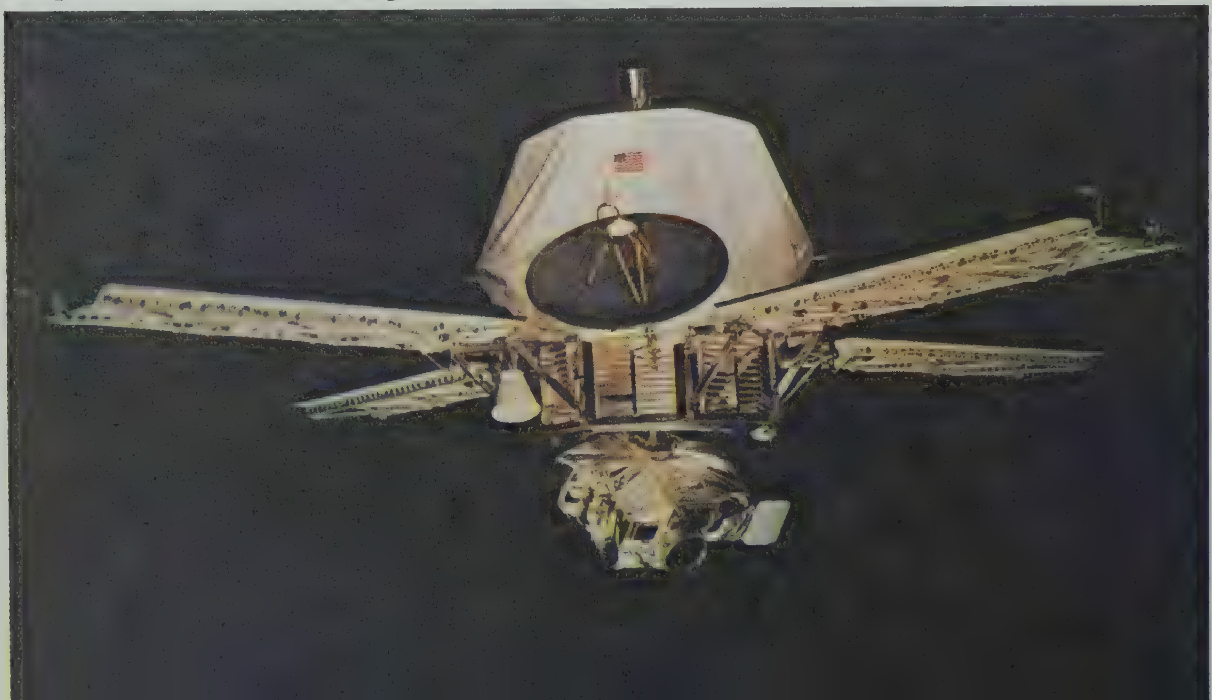
Space exploration now uses the following methods:

- Unmanned satellites—some remain in space; some are brought back to earth; some wander among the planets. Some stay in a sort of fixed position above earth. These are the ROBOTS (ROH-buts) which are mechanical "people." They respond to signals and "orders" from Ground Control.
- Manned satellites—Astronauts in capsules ferry around in space. Sometimes they "walk" in space. Some have landed on the moon. They then return to earth.
- Space stations—these are the laboratories in the sky (SKYLAB). The Skylab is a "motel" in the sky. It is unmanned part of the time. At other times astronauts leave the earth in capsules and dock with the Skylab. They live in it and experiment in it for many weeks. Then, they unlock their capsule and "taxi" back to earth.

In our next chapter, we shall read the thrilling adventures of some of these explorations.

Fig. 168–1

Mariner 10, a recent unmanned space-probing satellite.



UNDERSTANDING WHAT YOU HAVE READ

I. What are the two main ideas in Chapter 22?

1. To enter the earth's orbit, you must escape the earth's gravity.
2. To return to earth, we must slow down the capsule.
3. We now know how to get into the moon's orbit.
4. The skylab is an observatory.

II. In which paragraph do you find the answer?

1. What is the escape velocity for earth?
2. At what speed does a capsule go into the earth's orbit?
3. What are retro-rockets?
4. What are tracking stations?

III. Knowing What and Why

1. A capsule circling the moon moves more slowly than when circling the earth because
   a. the capsule has become heavier.
   b. there are no more rockets.
   c. the lunar module adds weight.
   d. the moon's gravity is weaker.
2. Tracking is a form of navigation using
   a. rockets.
   b. radios.
   c. spectroscopes.
   d. sextants.
3. Retro-rockets are used to
   a. slow the spaceship.
   b. get the spaceship out of the earth's pull of gravity.
   c. separate Stage 1 from Stage 2.
   d. fire the Lunar Module.
4. When a rocket first leaves the pad it goes
   a. up horizontally.
   b. straight up.
   c. straight up and down.
   d. many ways, depending on chance.

IV. Number, Please

Explain the meaning and importance of the following numbers.

1. 28 000 km/h
2. 38 900 km/h
3. 3050 m
4. 5-4-3-2-1-0

V. Understanding the Diagrams

Look at Fig. 165–1.

1. In an actual space shot, what takes the place of the tower?
2. Why are paths A, B, C and D all curved?
3. Where will the capsule's shell meet the largest amount of friction from the atmosphere?

VI. Unscramble the letters. Get the name of a monkey astronaut.

The answer is on Page 17.

O C T R K E (an engine for shooting capsules)

1

___ ___ ___ ___ ___ ___

H N A L U C (to send a rocket into space)

2

___ ___ ___ ___ ___ ___

P O L A L O (one of our space programs)

3

___ ___ ___ ___ ___ ___

B O S R E T O (first stage rocket)

4

___ ___ ___ ___ ___ ___ ___

Fill in the letters for a space monkey

___ ___ ___ ___

1 2 3 4

VII. For the Science Reporter

Draw up a list of the ten most famous astronauts. Write a sentence about the background of each one.

Title: Who's Who in the World of Astronauts.

23

TARGET
What have we accomplished in space?

Space Progress: Now and the Future

1. HANGING IN SPACE

You have probably watched a HELICOPTER (HEL-i-kop-ter) overhead. A helicopter in the sky is moving, of course. But it has the ability to circle around slowly. We say it *hovers*, or seems to hang in place.

In some cases, a satellite can be made to hover over the earth, just as a helicopter hovers. Scientists have found that when a satellite is 35 900 km from the earth's surface, it will orbit the earth at a slower speed than 28 150 km/h. It can stay in orbit at a speed of only 10 900 km/h. Now the satellite takes 24 h to orbit the earth. This is the same speed that it takes the earth to go around its own axis. This means that the satellite seems to "stand still" at the same spot on the earth. It hovers in place. Can you see the advantage of this? You are right! Such satellites can be used to "observe" the earth. They can "predict" weather over that spot and send radio and TV messages.

DO AND DISCOVER

Investigation 11: How can we show hovering?

What you do:

1. Paste a small piece of masking tape at the edge of the turntable of your record player. Start the turntable at a slow speed.
2. Hold a flashlight above the turntable to shine directly at the tape marker.
3. Follow the tape around with the beam of light.

What you see:

The beam of light shines over the tape at all times.

What you learn:

If the speed of revolution of the flashlight is equal to the speed of rotation of the turntable, the light hovers over the tape.

2. UNMANNED SATELLITES AT WORK

In Chapter 19, we spoke of satellites for weather observation. *Tiros* and *Nimbus* were early satellites. Their cameras took recordings and pictures of clouds and storms. They used solar batteries to power their cameras and instruments. ITOS-2, launched in 1971, is a modern weather satellite which sends cloud pictures, day and night. It was followed by GOES (1972), and then NOAA-5 and *Nimbus* 6.

Communication satellites are satellites that are transmitters in space. Some examples were *Syncom* and *Early Bird*. These satellites were in a hover orbit over the equator. Radio and TV transmitters on earth send out signals which are then bounced away from the satellites to other parts of the world. Radio waves travel in straight lines. The curve of the earth often stops them. However, when these waves go up to a satellite, they can then be beamed to other satellites and to all parts of the world.

Fig. 171—1

Intelsat is a six-continent communication system above the earth. ITOS, the 318 kg satellite, is equipped with weather sensors and cameras.

There is now a global (world wide) system of communication with over 80 member nations. These satellites are in position above the Atlantic, Pacific and Indian Oceans, linking six continents.

3. ROBOTS FOR SCIENCE

In addition to weather study and communication, other unmanned satellites are roaming in space to make scientific observations. They operate above the haze of the earth's atmosphere, check data and send information to earth laboratories.

The Orbiting Astronomical Observatory (O.A.O.) was launched on December 7, 1968. It carries eleven telescopes. It has studied stars. Its TV cameras send pictures to the earth's observatories. Solar cells supply the electricity. As the O.A.O. orbits 787 km above the earth, it "observes" young, hot stars, white, dwarf stars and red, super giant stars.

The O.G.O. (Orbiting Geophysical Observatory) is a 454-kg satellite which studies the earth's magnetism, space radiation and the earth's atmosphere. O.S.O. (Orbiting Solar Observatory) is designed to study the sun's behavior.

The ERTS (Earth's Resources Technology Satellite), launched in July, 1972, takes photos of the earth to make maps for the U.S. Geological Survey.

4. HUMAN TOURISTS IN SPACE

We have reached the goal to put humans into space and on the moon by simple stages.

VOSTOK 1, in 1961, showed we can live in space and return. Could we develop a force greater than the earth's gravity to get us into the moon's orbit? Apollo 8 in 1968 proved we could. Could an astronaut leave his capsule and "walk" in space? *Voskhod 2*, in 1965, showed we could. Could capsules dock in space and exchange astronauts? Again, the answer was, "Yes" (*Soyuz 4 and 5; Apollo 9*).

And, finally, could we actually land on the moon? The thrilling answer came on July 16, 1969.

YOU NOW KNOW

- Unmanned satellites are useful for communication, observation and scientific study.
- A slowly revolving satellite can hover over the earth in the same spot at a height of 35 900 km.
- Early space probes showed humans could enter space and return safely.

5. DESTINATION: THE MOON

The early steps were a success. The next call was for "Blast Off! Destination: The Moon."

This time, the rocket brought Apollo 11 to the moon's orbit. Then the LM settled down on the moon. Astronaut Mike Collins remained in the capsule which continued to orbit the moon. Astronauts Neil Armstrong and Edwin Aldrin descended to the moon in the LM. Then, wearing space suits, the two men got out of the LM and walked on the moon's surface. They took television pictures of themselves on the moon and transmitted the pictures to earth. We were able to see the astronauts exploring the moon while we were sitting in our living rooms. The astronauts set up experiments and collected samples of rocks and moon dust to bring back to earth.

The explorers returned to the LM. Then they blasted off the surface of the moon. Like a taxi, the LM delivered the astronauts to the Apollo 11 capsule, which was still in lunar orbit. Armstrong and Aldrin reentered the Apollo 11 capsule. The LM was "kicked off" into space. The capsule came back to earth and splashed down in the Pacific on July 24, 1969.

Fig. 172–1

Astronaut Neil Armstrong: The first human foot on the moon. *"That's one small step for man; one giant leap for mankind."*

Following Apollo 11, five more missions landed on the moon. (Apollo 13 became crippled in space, but returned safely to earth.) In all, six missions have landed twelve men on the moon.

The last of the missions was Apollo 17, which returned safely to earth in a splashdown on December 19, 1972.

6. WHAT DO ASTRONAUTS DO ON THE MOON?

And after they land? Astronauts are explorers and scientists. They have walked and "run" on the moon. This gave them the experience of moon gravity and their muscle reactions. They have driven on the moon in battery-powered cars. They have collected 382 kg of rocks to bring to earth. They have taken core samples of moon soil.

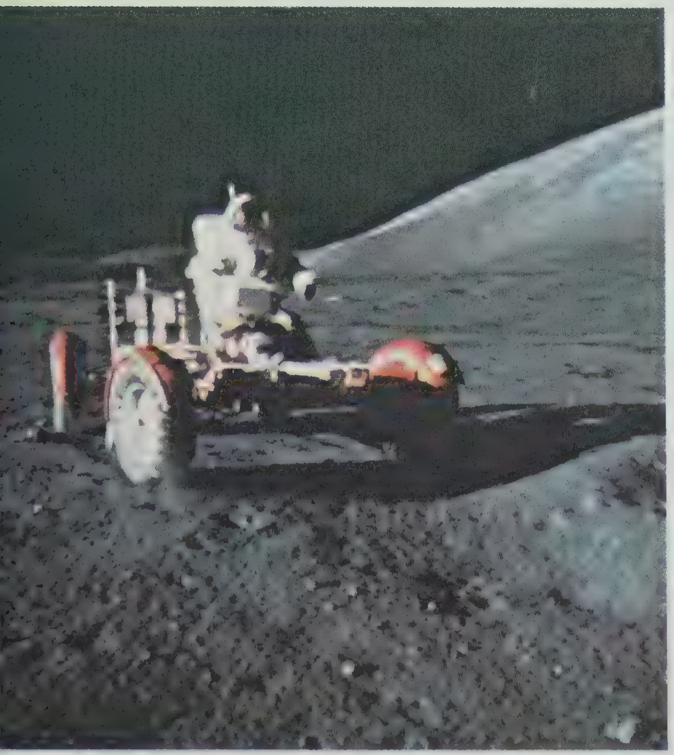


Fig. 173–1

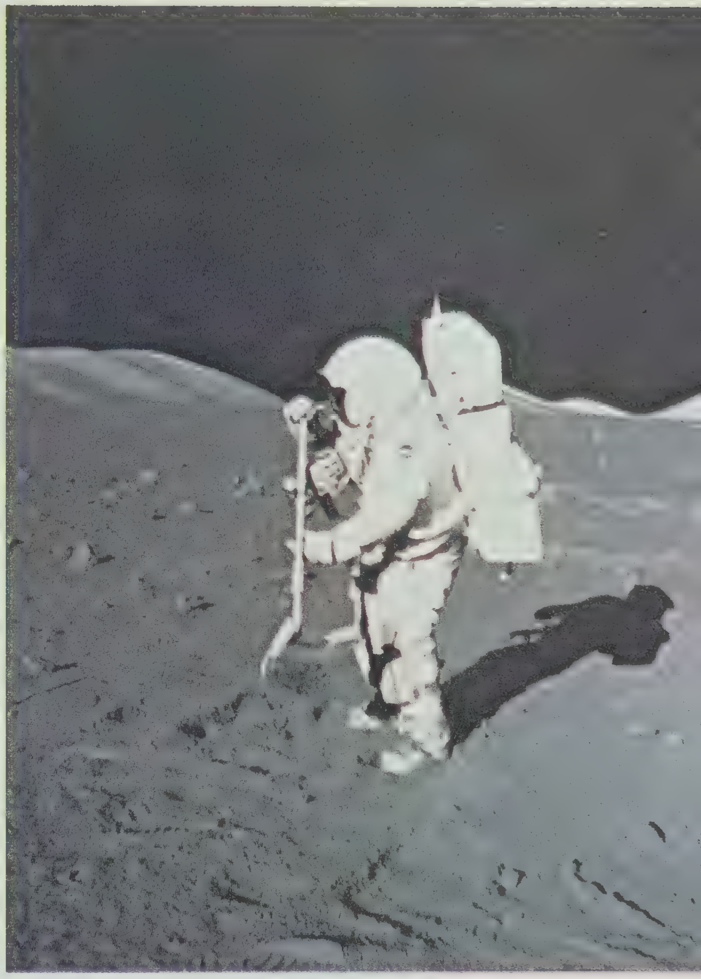
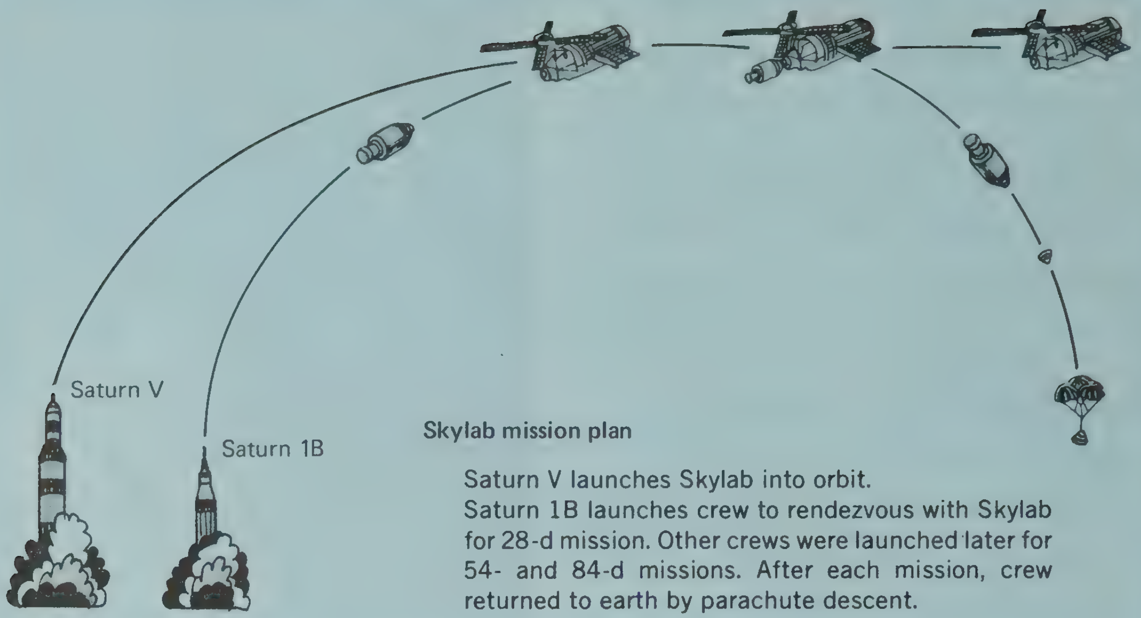


Fig. 173–2

From time to time, they return to the LM, take off their space suits, rest, eat, sleep, take notes and talk to Ground Control.

They take and send back thousands of pictures on film and by TV. They take measurements on their instruments.

Finally, they set up and leave *sensors* (instruments). These continue to operate after the astronauts leave. They keep sending back data to earth. Examples of some of the sensors are seismographs, heat-flow meters, solar wind meters, magnetometers, gravity meters and chemical analyzers.



Skylab mission plan

Saturn V launches Skylab into orbit.
Saturn 1B launches crew to rendezvous with Skylab for 28-d mission. Other crews were launched later for 54- and 84-d missions. After each mission, crew returned to earth by parachute descent.

Fig. 174–1

7. SKYLAB: THE SPACE STATION

On May 14, 1973, a Saturn V rocket boosted a 102-t, 20-m, two-story skylab workshop into orbit. There it was: the first manned space station, orbiting in space.

Later, three separate missions of astronauts were launched in Apollo capsules to rendezvous and dock with the skylab, 430 km above the earth.

What is the skylab? It is a giant "motel in the sky" which is vacant part of the time. Its workshop is about as big as a large house trailer. This gives the astronaut-scientists plenty of room for work, study, sleep and "living room." When the Apollo capsule reaches it in orbit, it hooks up with skylab through an air-lock tunnel. This allows the astronauts to move back and forth. The station is now 36 m long!

In the Skylab there were eight telescopes, many kinds of instruments, and, of course, provisions for life—food, medicine, etc. As the skylab orbited, it passed over 75% of the earth's surface. Experiments in biology included analysis of the astronaut's blood and excretions; their metabolism; and responses to weightlessness. On Mission 3, observations were made on a small "zoo" traveling as "passengers": minnows, mice, spiders and flies. The telescopes gave them observations of Mercury, the Earth, the comet, Kohoutek, hurricane and snow patterns. They also photographed many areas of the earth for map-making.

In all, three crews went and returned to Skylab. Mission 1 stayed 28 d; Mission 2 stayed 59.5 d, and Mission 3 stayed 84 d. The previous record for man in space was in Soyuz 11, 23 d in 1971. The latest record for man in space is in Soyuz 27, 96 d in March, 1978.

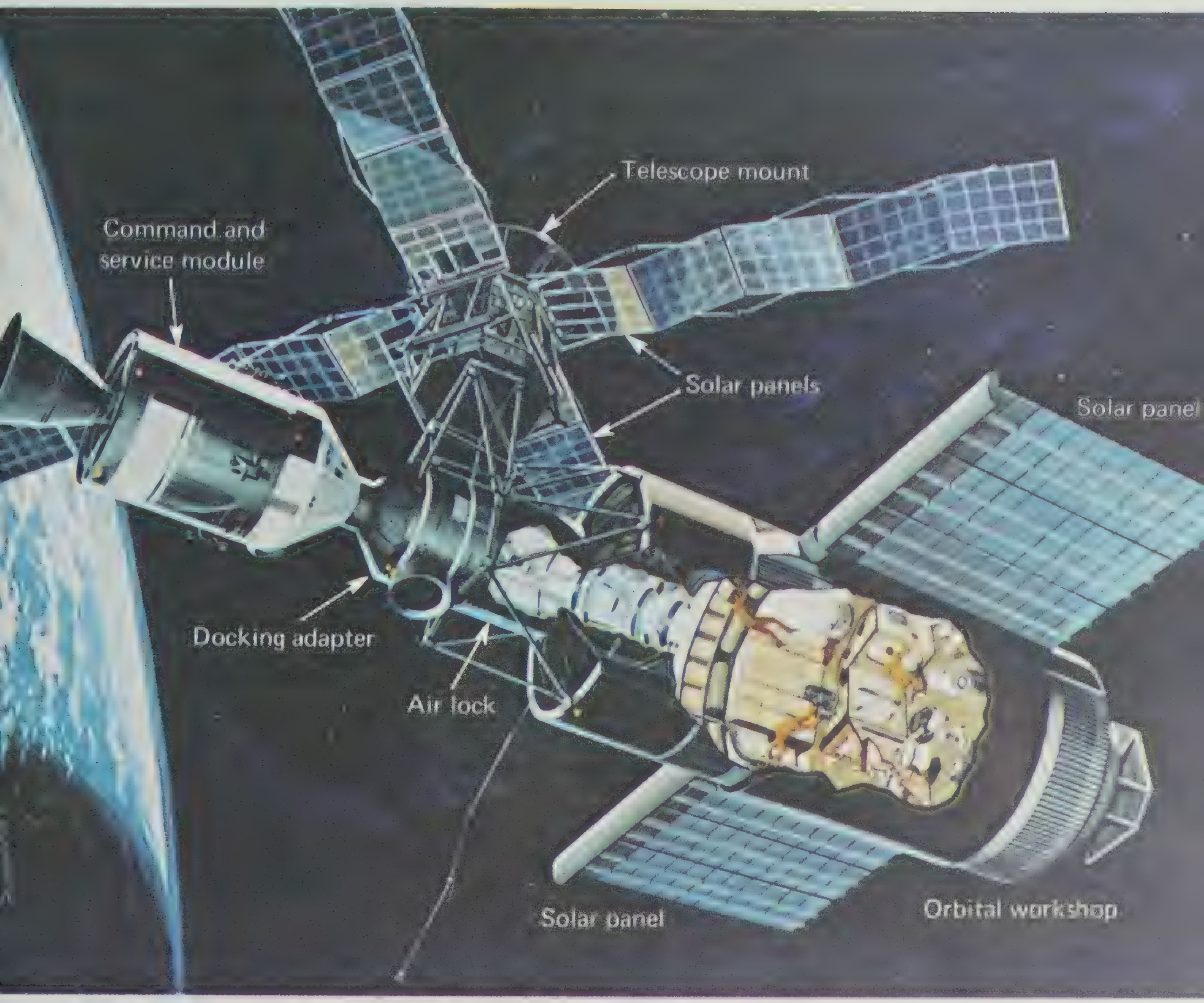


Fig. 175–1

The Skylab. What are the jobs of the parts shown? By the way, did you know that 19 experiments in Skylab were suggested by 19 U.S. high school students?

8. AND THE FUTURE?

The future in space exploration may be science fiction to some. But when we think of how far we have come in only 20 years, almost anything is believable.

There have been many more unmanned satellites. Viking I (U.S.) was launched August 20, 1975 and landed on Mars on July 20, 1976 for detailed scientific research. Viking II was launched on September 9, 1975 and landed on Mars September 3, 1976. On September 5, 1977, Voyager I (U.S.) was launched with a destination of Uranus and Jupiter. Then Voyager II was launched September 20, 1977 with Saturn as its destination. Encounter dates will be Jupiter 1979, Saturn 1981, and Uranus 1986.

Space Shuttle, a new manned space transportation system began its flights in the summer of 1977. This vehicle is designed to enter space like a rocket; the orbiter, after completing its job, will re-enter the earth's atmosphere like an ordinary airplane.

Aren't *you* glad you will be around to see all this—and much, much more!

YOU NOW KNOW

- The Apollo Mission (11 through 17) brought 12 astronauts to the moon for exploration and scientific study.
- The Skylab is a space station where astronauts can live and work for long periods of time.
- The Space Shuttle was launched in 1976.
- A Mars landing came about twice in 1976.

Fig. 176–1

Reaching beyond our earth was once only a dream. Now that dream has been reached.

UNDERSTANDING WHAT YOU HAVE READ

I. What are the two main ideas in Chapter 23?

1. Satellites can revolve at low speeds.
2. Some satellites, unmanned, are in orbit and doing useful work.
3. Space stations have given the U.S. a space advantage.
4. Manned space flights have brought us to the moon and may soon bring us to Mars.

II. In which paragraph do you find the answer?

1. What is meant by a hover satellite?
2. What is an O.A.O.?
3. What procedure did Soyuz 4 carry out?
4. What was the accomplishment of Apollo 11?

III. Knowing What and Why

1. Early Bird is
   a. a communications satellite.
   b. an Australian tracking station.
   c. the U.S. President's personal spaceship.
   d. the project to follow the Apollo program.
2. The Lunar Module used in a moon trip
   a. brings the astronauts to splashdown.
   b. was left in space.
   c. is waiting on the moon to go to Mars.
   d. was brought to the Hayden Planetarium.
3. The Skylab is best known for
   a. the many animals it carried.
   b. the workshop for long-duration scientific missions.
   c. the capsule where astronauts could eat proper food.
   d. its direct TV link to Soviet Russia.
4. When Apollo 11 reached the moon's orbit,
   a. its speed was reduced.
   b. its speed went up.
   c. it exploded.
   d. it opened its parachutes.

IV. True or False? Explain your answers.

1. The Apollo 17 crewmen were the first human beings ever to look upon the earth from space.
2. The Soyuz docking was a forerunner to a space station.
3. Mariner 10 is the ship that recovers astronauts in the ocean.

V. Match the words with the correct word or phrase inside the parentheses.

1. Communication satellite (Vostok, Tiros)
2. Lunar Module (moon taxi, moon missile)
3. Gagarin (Shephard, Goddard)
4. 38 900 km/h (retro-rockets, escape velocity)
5. Pioneer 10 (Mariner 9, Sputnik 1)

VI. For the Imaginative Writers

Imagine you were an astronaut on Apollo 17. Write a story of your trip to the moon and back.

VII. Reaching Out . . .

Write to the National Aeronautics and Space Administration, Washington, D.C. 20546. Ask for free booklets on the latest space developments.

Glossary: What Does It Mean?

Command Module		The part of a manned spaceship which holds the men and/or instruments.
cosmonaut	COZ-muh-nawt	The Russian name for an astronaut.
Early Bird		A satellite used to relay radio and TV messages.
Echo		A satellite used to send radio and TV signals back to earth. It has the same function as the Early Bird.
ERTS		Earth Resources Technology Satellite.
fuel		The part of a rocket propellant which burns.
fuel cell		A special cell that burns hydrogen and oxygen to release energy.
G-force		The force exerted on an object due to gravity or speed of travel.
Gagarin, Yuri	ga-GA-rin, YOOR-ee	The Russian cosmonaut (astronaut) who was the first man to be in space.
gantries	GAN-treez	Temporary towers which enable workers to reach all parts of the rocket.
GOES		Geostationary Operational Environmental Satellite.
Goddard, Dr. Robert	GOD-ard	An American scientist who was the first person to launch a rocket with liquid fuel.
Ground Control		The men and instruments on earth that guide and advise the operations of a spaceship.
heat shield		Layers of a material that protect a capsule from burning up as it reenters the earth's atmosphere.

helicopter	HEL-i-kop-ter	An aircraft which can hover above an object as well as go forward and up and down.
INTELSAT		A group of world-wide space satellites used to beam radio and TV signals among six continents.
ITOS		Improved Terrestrial Observation Satellite.
launching pad		The area where a rocket or spaceship stands before it is sent into space.
launch vehicle		Another name for a rocket used when it sends something else into space, such as a capsule.
Lunar Module	MOD-yool	The part of the spaceship that brought astronauts to the moon's surface.
Mariner		One of several unmanned satellites in orbit to study planets and space.
NASA		Stands for National Aeronautics and Space Administration. It is the United States Government's space agency.
O.A.O.		Stands for Orbiting Astronomical Observatory. It is a satellite which will study the stars.
oxidizer		Part of a rocket propellant which causes the fuel to burn.
propellant	pro-PEL-unt	The mixture of a liquid fuel and an oxidizer used to power a rocket.
recovery area		The area chosen for a space capsule to land and be picked up.
rendezvous	RON-day-voo	The meeting of two space capsules in space.
retro-rockets		Rockets that turn or slow down the capsule as it begins to re-enter the earth's atmosphere.
sensors	SEN-sorz	Scientific instruments.
Service Module		The part of a spaceship which stores rockets, fuel cells, and so forth.

Skylab		The U.S. Space Station in orbit 430 km above the earth.
solar cell		A cell made of boron and silicon crystals; it converts sun energy to electrical energy.
Space Shuttle		A Rocket-fired capsule which goes to a space station; return is by airplane.
space station		An artificial satellite which serves as a base for future space trips; a sky lab.
splash down		The landing of a space capsule in the ocean.
Sputnik I	SPOOT-nik	The first man-made satellite to orbit space. (U.S.S.R. 1957)
thrust		The force which pushes a rocket.
Tiros		A satellite which broadcasts weather conditions to the earth.
tracking stations		Stations set up around the world to follow a spacecraft's radio signals.
Van Allen belts		Zones of radiation that surround the earth.
weightlessness		Being in the state of free fall. Objects seem to float in space.

Acknowledgments

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TABLES OF MEASURE

Length

1000 mm (millimetres) = 1 m (metre)
0.001 m (metre) = 1 mm (millimetre)
100 cm (centimetres) = 1 m (metre)
0.01 m (metre) = 1 cm (centimetre)
10 dm (decimetres) = 1 m (metre)
0.1 (metre) = 1 dm (decimetre)
0.001 km (kilometre) = 1 m (metre)
1000 m (metres) = 1 km (kilometre)

Mass

1000 g (grams) = 1 kg (kilogram)
1 g (gram) = 0.001 kg (kilogram)
1000 kg (kilograms) = 1 t (tonne)
1 kg (kilogram) = 0.001 t (tonne)

Capacity

1000 mL (millilitres) = 1 L (litre)
1 mL (millilitre) = 0.001 L (litres)

Time

60 s (seconds) = 1 min (minute)
60 min (minutes) = 1 h (hour)
24 h (hours) = 1 d (day)
365 d (days) = 1 a (year)

SOME IMPORTANT TEMPERATURES

°C	
−273	Absolute zero. All motion of molecules stops.
− 79	Carbon dioxide gas becomes solid (dry ice)
− 39	Mercury freezes
0	Ice melts; water freezes
20	Average room temperature
37	Normal human body temperature
65	Pasteurization of milk (for 30 min)
100	Water boils (to steam)

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